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New Pages for Beginners and Savvy Astronomers

# Astronomy®

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January 2002

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## The Making of an Aurora

## Revealing a Mysterious Shadow Universe

## The Harvard Astronomer Who Took On the FBI

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R.A. manual slow-motion control
Diffraction-limited EMC super multi-coated optical system
Declination lock
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Autostar II hand controller mounts on tiltable holder
Control panel with 7 connector ports, including two RS-232 serial interface ports
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*Patents pending on Autostar Easy Align, system architecture, and GPS alignment procedure*

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# Meade® LX200GPS: the most important advance in Schmidt-Cassegrain technology in ten years is here.

## For the visual observer, the astrophotographer, the CCD imager: all the telescope you could possibly have imagined.

For the advanced amateur, new Meade LX200GPS telescopes offer absolutely state-of-the-art optical, mechanical, and electronic performance unmatched by any competing models. Standard-equipment features include:

**Precision GPS Alignment:** Telescope alignment is accomplished automatically using integrated true-level and North electronic sensors in combination with a 16-channel GPS receiver located in the left-hand fork arm. Magnetic declination compensation is designed into the software and automatically engaged. Just press the *ENTER* button on the Autostar II hand controller and watch as the telescope slews at 8°/second to its first alignment star. *Competing GPS telescopes use a 12-channel receiver (resulting in slower and less reliable position acquisition), do not include any magnetic declination compensation, and can easily result in first-alignment-star errors of up to 20° or more.*

AUTOSTAR II
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MODE
GO TO

**Autostar II accesses over 125,000 database objects.**

**Revolutionary new rear-cell systems designed for the advanced visual observer, astrophotographer and CCD imager —** systems that enable new levels of precision in focusing in all applications and in image centering on CCD chips:

**Primary Mirror Lock:** Flip a knob located just above the manual coarse-focus knob and lock the telescope's primary mirror rigidly in place. Used in conjunction with the Zero Image-Shift Microfocuser *(below)* the primary mirror lock completely cancels any residual image shift while focusing during visual, photographic, or CCD imaging applications.

**Zero Image-Shift Microfocuser:** Now you can obtain the most precise image focus possible — truly to a microscopic level — during visual and astrophotographic applications, and, during CCD applications, simultaneously maintain precise image centration on even the smallest CCD chips. Included as standard equipment with all LX200GPS Schmidt-Cassegrain models, the Meade Zero Image-Shift Microfocuser operates at 4 different speeds from extremely slow to fast; the entire microfocusing operation is actuated through the Autostar II handbox. Coarse manual focusing is effected through the telescope's manual focus knob.

**Autostar II:** The new Autostar II control system provided with LX200GPS models includes all of the features that made previous LX200 models the largest-selling serious telescopes in the world. In addition, Autostar II includes an expanded 3.5 Megabyte memory, permitting a greatly enlarged database of more than 125,000 celestial objects, a database that is immediately accessible on the Autostar II display. A partial listing of the Autostar II database:

| Library | No. of Objects |
|---|---|
| New General Catalog (NGC) | 7840 |
| Index Catalog (IC) | 5386 |
| Messier Catalog (M) | 110 |
| Caldwell Catalog | 109 |
| Named Objects | 227 |
| Herschel Catalog | 400 |
| Abell Catalog of Galaxy Clusters | 2712 |
| Arp Catalog of Irregular Galaxies | 645 |
| Uppsala Galaxy Catalog | 12,940 |
| Morphological Catalog of Galaxies | 12,939 |
| General Catalog of Variable Stars | 28, 484 |
| SAO and Hipparcos Star Catalogs | 31,090 |

**SPECIFICATIONS: 7", 8", 10", and 12" LX200GPS —** Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; primary mirror lock; 4-speed zero image-shift microfocuser; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and 7-port multi-function control panel, including two RS-232 serial interface ports; manual and electric slow-motion controls on both axes; Autostar II control system with 3.5 Megabyte flash memory, digital readout display, permanently programmable Smart Drive and 9-speed drive controls on both axes, High-Precision Pointing, and GO TO controller; 125,000-object onboard celestial software library; 12vDC telescope power supplied from internal battery compartments accepting 8 (user-supplied) C-cells (optional 25 ft. cords are available for powering from auto cigarette lighter plug or from 115vAC); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

### *INTRODUCTORY PRICES*
### MEADE LX200GPS SCHMIDT-CASSEGRAIN TELESCOPES

| | |
|---|---|
| 8" LX200GPS | **$2495** |
| 10" LX200GPS | **2995** |
| 12" LX200GPS | **3995** |
| 7" LX200GPS Maksutov-Cassegrain | **2995** |

**Packing & shipping charges** in the 48 states: 8" – $105; 10" – $145; 12" – $215; 7" – $125. Prices shown are suggested U.S. national mail-order retail prices.

**Scheduled Delivery:** October, 2001.

### A COMPARISON OF GPS SCHMIDT-CASSEGRAIN TELESCOPES

| | Meade LX200GPS | Competing 11" GPS* |
|---|---|---|
| GPS Receiver | 16-channel | 12-channel |
| Magnetic declination compensation | yes | no |
| True-level electronic sensor | yes | no |
| Primary mirror lock | yes | no |
| Zero image-shift microfocuser | yes | no |
| Maximum slew speed | 8°/second | 3°/second |
| Memory | 3.5-Meg flash | 1.0-Meg flash |
| GO TO pointing precision | 2-arcmins | unstated |
| High-precision pointing mode | yes; permits GO TO pointing precision within 1-arcmin | no |
| Permanent Periodic Error Correction | yes, both axes | one axis only; second axis unprogrammable |
| Object database | 125,000 objects | "40,000+" |
| Encoder resolution | 0.10 arcsecs | 0.26 arcsecs |
| Internal battery compartments for battery powering | yes; batteries located internal to fork arms | no |
| RS-232 software download | yes; object libraries and software downloads available | not currently available on factory website** |
| Tracking calibration | not required | recommended after changes in telescope position or load |

*Based on sample and instruction manual received in 7/01. ** As of 9/15/01.

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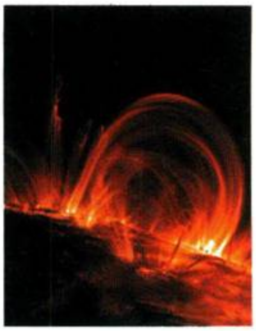

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**COVER PHOTO:** NASA/TRACE

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**78 Canis Major**
From *The Glorious Constellations,* © 1991; Harry N. Abrams, Inc.

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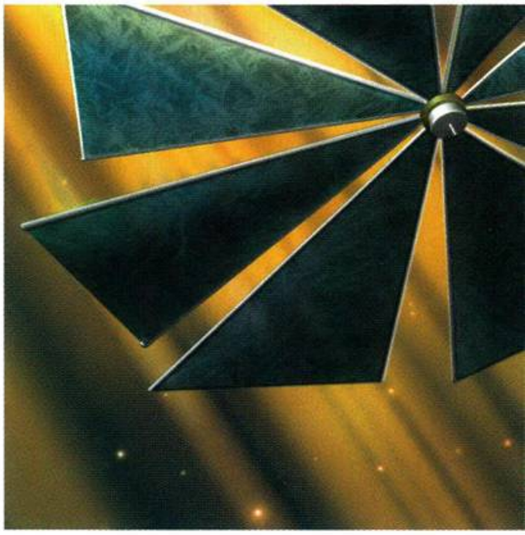

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**36 Revealing a Mysterious Shadow Universe** © Anglo-Australian Observatory

## BEHIND THE SCENES

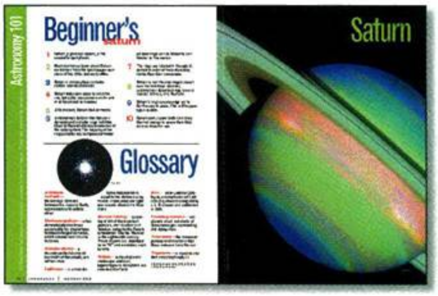
BY BONNIE BILYEU GORDON

# What's New

We're ringing in the New Year with two new departments to help you fulfill your observing resolutions all year round. One 4-page section is devoted to "The Savvy Astronomer" (see page 88), the intermediate to advanced astronomy buff who wants constantly greater challenge. The other 4-page section, "Astronomy 101" (see page 84), is devoted to beginners in the hobby and offers an array of encouragement and tips.

In "Astronomy 101," you'll find a tip-filled and ongoing diary of an absolute beginner. Jerry Burstein will take you with him on the adventure as he discovers the joy of observing. He will learn how to read star charts, discover constellations, and uncover the secrets of viewing the night sky with naked eye, binoculars, and small telescopes. If you have never given observing a try but always wanted to, here's your chance to go along with Jerry month by month and follow his example.

Other rewards in "Astronomy 101" include a full-page, collectible image of a beautiful sky target, accompanied by ten of the most important facts about it. In addition, we present a sky chart of an easy naked-eye object with guidance on how to find and observe it. And we introduce a glossary that focuses on words and concepts raised in stories throughout the current issue. This could be useful for beginners and some of the rest of us too.



**The opening pages of Astronomy 101 (see page 84) offer up a collectible image, with fun facts on the subject and a glossary that illuminates the newest astronomical concepts.**

"The Savvy Astronomer" includes a feature story just for advanced observers. This month we will focus on challenging nebulae in Perseus. In future issues, we'll publish astrophotography lessons, reviews of new equipment, or build-it-yourself projects.

Around and amid the main story, you will find short boxes that include tips for finding faint comets and the favorite sky objects of a well-known amateur astronomer. (In this issue, Tom Polakis makes the picks.) We also include a brief writeup of Ireland's Whirlpool Star Party. Other star parties will be covered from time to time.

Supplemental materials for "Astronomy 101" and "The Savvy Astronomer" will appear online at Astronomy.com. Look for them. *Astronomy* editors are eager to hear from you about these new efforts. Do you have ideas we might include?

While you're thinking about writing to us, you might make a stab at sharing a sky-gazing story. We love to have short observing tales to run in "Hot Shots."

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1. **Enter on the Autostar display the astronomical object you want to see.**
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## Now you can buy a Meade Schmidt-Newtonian telescope with Autostar dual-axis GO TO drive system for as little as $599, *complete!*

*Shown:* Meade 8" f/4 LXD55 Schmidt-Newtonian Telescope with standard-equipment Autostar Control System

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*Shipped complete per specifications below:*

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| 8" LXD55 Schmidt-Newtonian | **729** |
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**Packing & shipping charges** in the 48 states: 6" – $75; 8" – $85; 10" – $95. Prices shown are suggested U.S. national mail-order retail prices.

**SPECIFICATIONS: 6", 8", and 10" LXD55-Series Telescopes** — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; all-metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.

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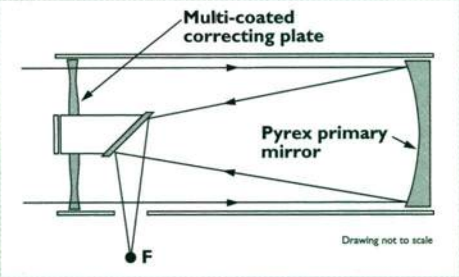
## Every Meade LXD55-Series Schmidt-Newtonian telescope includes this listing of standard equipment:

**Schmidt-Newtonian optical systems:** Manufactured entirely at the Meade Irvine facility, LXD55 diffraction-limited Schmidt-Newtonian optics yield pinpoint stellar images over extremely wide fields, with *one-half* the coma of paraboloids of the same focal ratios. Combined with fast f/4 (8", 10") or f/5 (6") optics, the standard-equipment Super Plössl 26mm eyepiece yields an actual field in excess of 1.3°, for brilliant, rich-field imaging of nebulae, galaxies, and star clusters. High-power lunar and planetary images reveal subtle detail often lost in telescopes of lesser optical resolution. The optics are mounted in machined aluminum cells fitted to white-enameled metal tubes; each tube accepts the giant Meade rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces.



**The Meade Schmidt-Newtonian Optical System.**

**LXD55 Equatorial Mount:** Designed by Meade engineers and manufactured of machined aluminum for high-performance photo-visual observing, the new Meade LXD55 mounting moves effortlessly across the skies in either tracking or automatic GO TO modes. Included is an illuminated polar viewfinder for quick, precise polar alignment.

**All LXD55 telescopes** include an illuminated polar alignment finder as standard equipment.

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*Automatic GO TO capability* at 4.5°/second on both axes simultaneously, to 30,223 database objects, including:

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50 objects in the Solar System; 8 major planets from Mercury to Pluto; the Moon; 26 asteroids; 15 comets.

50 Earth satellites; 200 memory locations for user-defined objects.

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*Automatic sidereal-rate tracking in R.A.* keeps objects precisely centered in the field.

*Control of the telescope through your PC and full upgradability over the Internet,* using the RS-232 serial interface. (Requires optional #505 Connector Set.)

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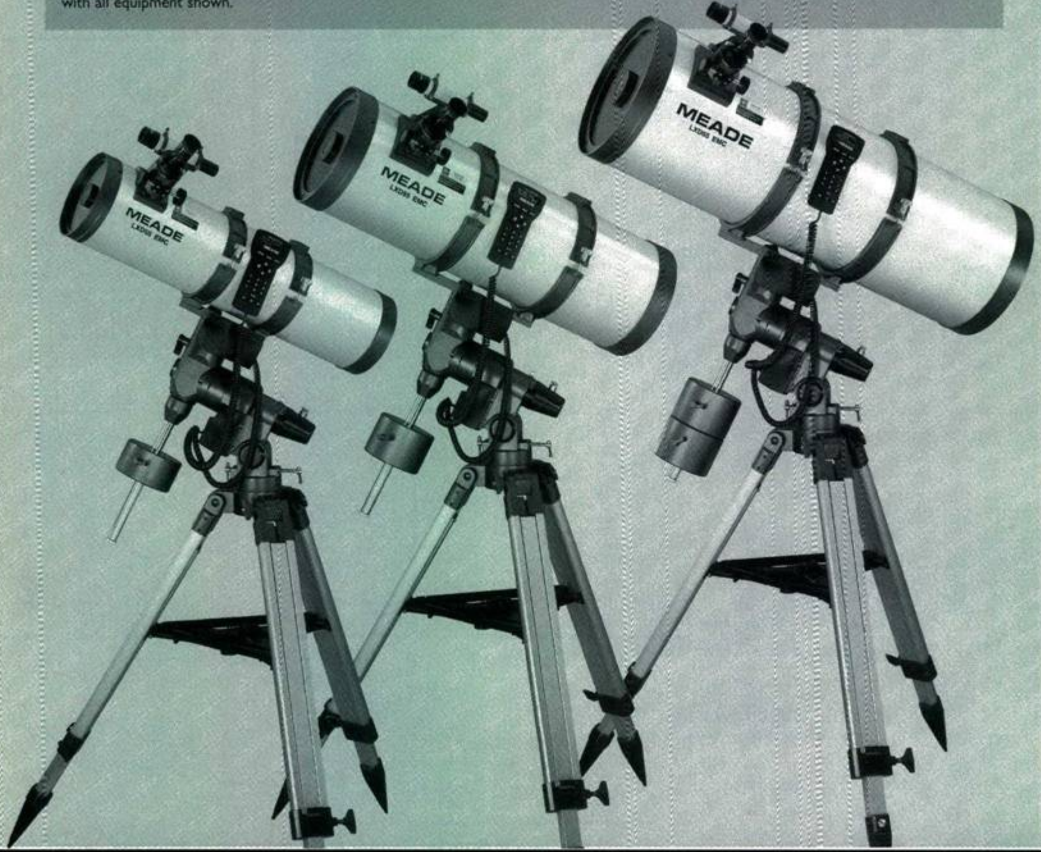
12vDC
ON - OFF
AUX
DEC

**The LXD55 control panel** is located below the upper bearing of the polar axis.

***Below, left to right:* Meade 6" f/5, 8" f/4, and 10" f/4 LXD55 Schmidt-Newtonian telescopes.** Each telescope is shipped complete with all equipment shown.



**Meade LXD55 Schmidt-Newtonians** open up the skies to images and capabilities previously unavailable in telescopes of their aperture and price level. Consider what a Meade LXD55 telescope can do for your observing program:

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| **56mm** (52°; 2") | | **199.95** (7.02) |

## Series 4000™ 2x Apochromatic Barlow Lens

**#140:** The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

**$79.95** (5.26)

## Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

**Super Wide Angle** (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

## Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

**Ultra Wide Angle** (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

## World's Most Advanced Illuminated Reticle Eyepiece

**Series 4000 Plössl 9mm,** with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

**$149.95** (6.14)

**Series 4000 Plössl 9mm**—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

**$129.95** (5.26)

## Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

**Series 3000 Plössls** (4-elements; 1.25"; 50°)

**5, 6.7, 9.5, 16, 25mm** each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

**Series 4000 Photo-Visual Color Filters** (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

**#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue** each **$14.95** (2.73)

| | |
|---|---|
| **Set #1**–4 filters: #12, #23A, #58, #80A | **49.95** (4.54) |
| **Set #2**–4 filters: #11, #25A, #47, #82A | **49.95** (4.54) |
| **Set #3**–4 filters: #8, #21, #38A, #56 | **49.95** (4.54) |

**Series 4000 Moon Filter (#ND96):** Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#911B
#910B
#908B
#911N
#910N
#908N

**Series 4000 Nebular Filters**—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

| | |
|---|---|
| **#908B**–Threads into 1.25" eyepieces, 26mm dia. | **79.95** (4.54) |
| **#910B**–Threads into 2" eyepieces, 44mm dia. | **119.95** (5.26) |
| **#911B**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **99.95** (5.26) |
| **#908N**–Threads into 1.25" eyepieces, 26mm dia. | **89.95** (4.54) |
| **#910N**–Threads into 2" eyepieces, 44mm dia. | **129.95** (5.26) |
| **#911N**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **119.95** (5.26) |

#911X
#910X
#908X

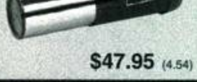
**Series 4000 Oxygen-Ⅲ Filters** Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-Ⅲ lines to tremendously enhance observable nebular structural detail in all telescopes.

| | |
|---|---|
| **#908X**–Threads into 1.25" eyepieces, 26mm dia. | **99.95** (4.54) |
| **#910X**–Threads into 2" eyepieces, 44mm dia. | **159.95** (5.26) |
| **#911X**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **149.95** (5.26) |

## Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

## 2x Telenegative Barlow (1.25")



**#122:** Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

**$47.95** (4.54)

## #905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

## 2x Short-Focus Barlow (1.25")

**#126:** Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

## 2x-3x Variable Barlow (1.25")

**#127:** Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

**$59.95** (4.54)

## 2" Diagonal Mirror

**#929:** Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

**#929** or **#930,** each: **$99.95** (6.85)

## 45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

**$42.95** (3.86)

## Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

**#1206 Electric Focuser:** Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

**#1205 Electric Focuser:** For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

**$169.95** (7.88)

## #777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

**$79.95** (6.85)

## Vibration Isolation Pads

Designed by Meade engineers, these isolation pads reduce typical telescope-tripod vibration damping times to *less than one second*. A tremendous aid for both visual and photographic astronomy. Place one pad under each tripod leg. #895 Vibration Isolation Pads, per set of three:

**$49.95** (6.85)

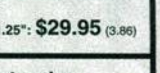
## MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

**$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

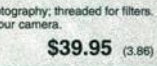
## Camera Adapters



Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

**.965": $27.95**; **1.25": $29.95** (3.86)

## Variable-Projection Camera Adapter (1.25")



Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

**$39.95** (3.86)

## Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

**$39.95** (3.86)

## T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

**$26.95** (3.86)

## CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

*"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope."* — Jack Newton

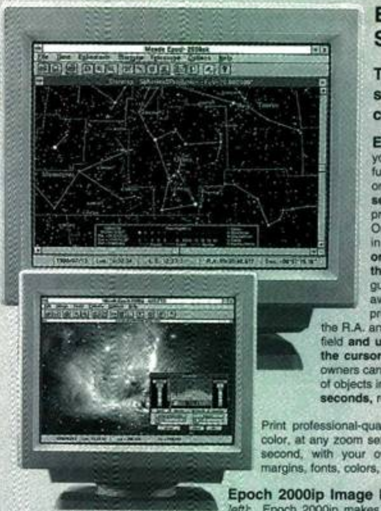
**#644 Flip-Mirror System:** Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

**#647 Flip-Mirror System:** Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-10; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

**#157 1.25" Adapter:** Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

#644

#647



## Epoch 2000® Sky Software

### The most powerful astronomical software ever made available can now be yours for only $99!

**Epoch 2000sk** *(upper display at left)*: Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

**Epoch 2000ip Image Processing Software** *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

| | |
|---|---|
| **EPOCH 2000sk Sky Software:** 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM for Windows 95, 98, 2000, ME, NT, and XP | **$99** |
| **LX200 Interface Cable:** for Meade LX200 operation by Epoch 2000sk | **25** |
| **EPOCH 2000ip Image Processing Software:** Supplied on CD-ROM for Windows 95, 98, 2000, ME, NT, and XP | **99** |

## Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture.

**$149.95** (5.26)

## Plössl 25mm Illuminated Reticle CCD Framing Ocular

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25".

**$129.95** (4.54)

## #825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing.

**$49.95** (4.26)

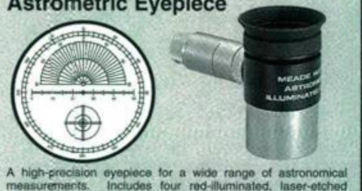
## #64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

## #932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics. **$49.95** (3.86)

## MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

## Series 4000™ 8mm – 24mm Zoom Eyepiece

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **$219.95** (6.38)

## ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, *etc.* Includes steel latches & key.

**#774** Case for ETX-90 models: **99.95** (8.58)

**#776** Case for ETX-105EC: **99.95** (8.58)

**#775** for ETX-125EC: **149.95** (13.38)

## Dew Shields for ETX®

Threads into the front-lens cell and effectively inhibits the formation of dew on the lens surface.

| | |
|---|---|
| **#670** for ETX-60/70 | **19.95** |
| **#673** for ETX-90 | **24.95** |
| **#675** for ETX-105 | **27.95** |
| **#678** for ETX-125 | **29.95** |

## Advanced Field Tripod for ETX-125

**#887:** Yields *rock-solid* stability for sensitive applications of the ETX-125, even at high magnifications. **Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125.** Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport.

**$349.95** (14.00)

## Tripod Adapter for ETX-125

Included with the #887 Tripod *(above)*, the #889 Adapter is available separately and permits attachment of ETX-125 directly to any Meade LX10, LX50, or LX200 Schmidt-Cassegrain Field Tripod for altazimuth observing or to any Meade Schmidt-Cassegrain Tripod-with-Equatorial Wedge or Superwedge for equatorial applications. **#889 Adapter:**

**$69.95** (7.70)

## ETX® Deluxe Field Tripod

**#884:** Constructed of strong, lightweight steel; designed specifically for ETX-90, ETX-105, and ETX-125 Astro Telescopes. Tripod height adjusts from 25" to 43", for seated or standing observations. Graduated scale for elevation angle from 20° to 90° permits precise polar alignment of the telescope for astronomical applications. Tripod tilts and locks at 90° for terrestrial applications or for altazimuth use with Autostar. Telescope attaches to tripod in seconds with 2 thumbscrews. **Includes custom-fitted carry bag *(shown)* with pocket for accessories.**

**$199.95** (10.00)

## ETX® Carry Bag

Soft-padded Cordura-type carry bag with shoulder strap; permits storage of any 90mm ETX model, plus table tripod legs, eyepieces, other accessories.

**$36.95** (5.26)

## Electric Focusers for ETX®

Meade-engineered for smooth, rapid focusing with any ETX model. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus ETX/EC models through the telescope's hand controller.

**#1244 Electric Focuser** for all ETX-90 and ETX-105 models: **$119.95** (6.85)

**#1247 Electric Focuser** for ETX-125 models: **$119.95** (6.85)

# HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

**ASTRONOMICS, Norman, OK.**
**Orders: 800-422-7876; Info.: 405-364-0858.**

**FOCUS CAMERA, Brooklyn, NY.**
**Orders: 800-221-0828; Info.: 718-436-6262.**

**LUMICON, Livermore, CA.**
**Orders: 800-767-9576; Info.: 925-447-9570.**

**OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.**
**Orders & Information: 800-483-6287.**

**RIVERS CAMERA, Dover, NH.**
**Orders: 800-245-7963; Info.: 603-742-4888.**

**SHUTAN CAMERA & VIDEO, Chicago, IL.**
**Orders & Info.: 800-621-2248; IL: 847-367-4600.**

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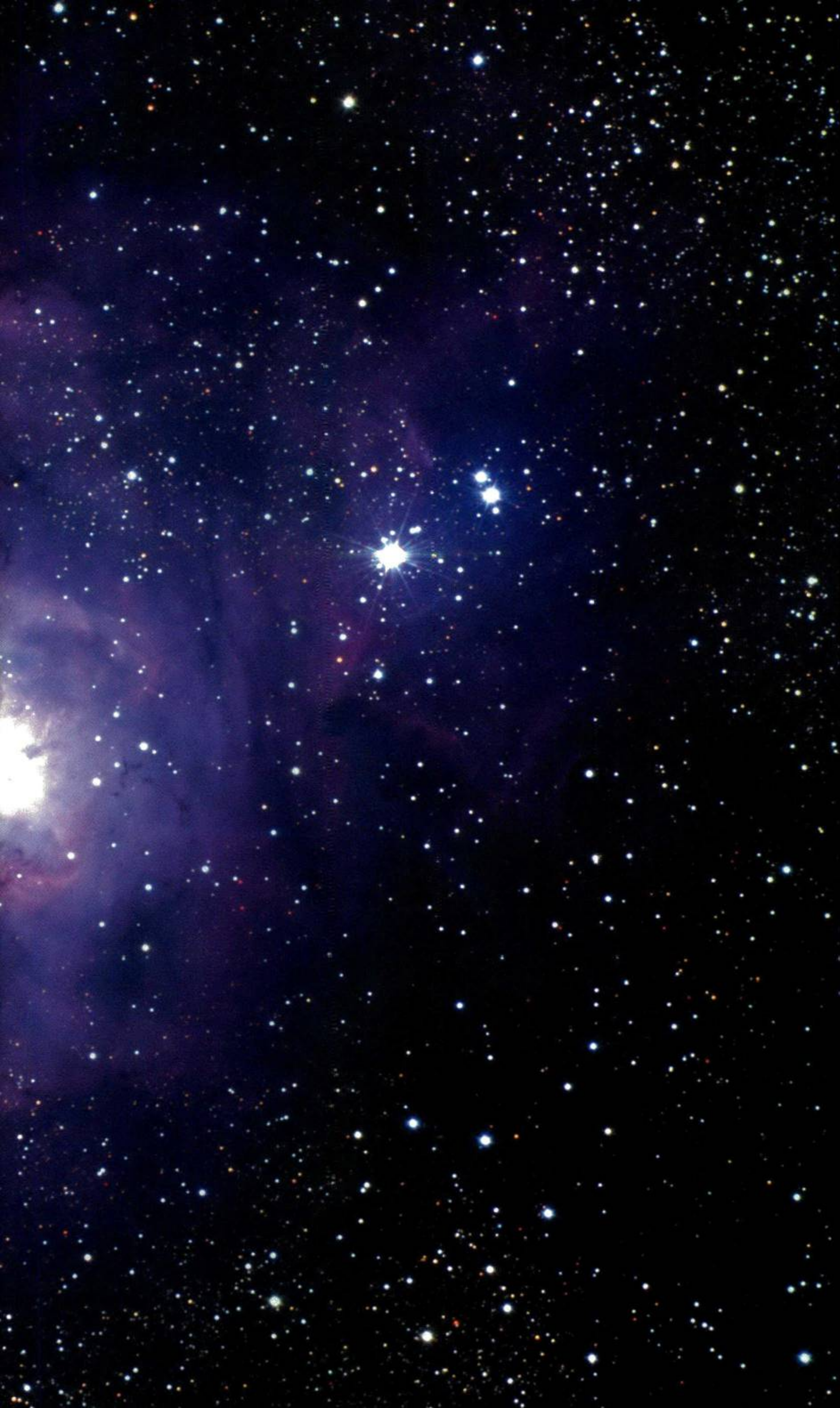


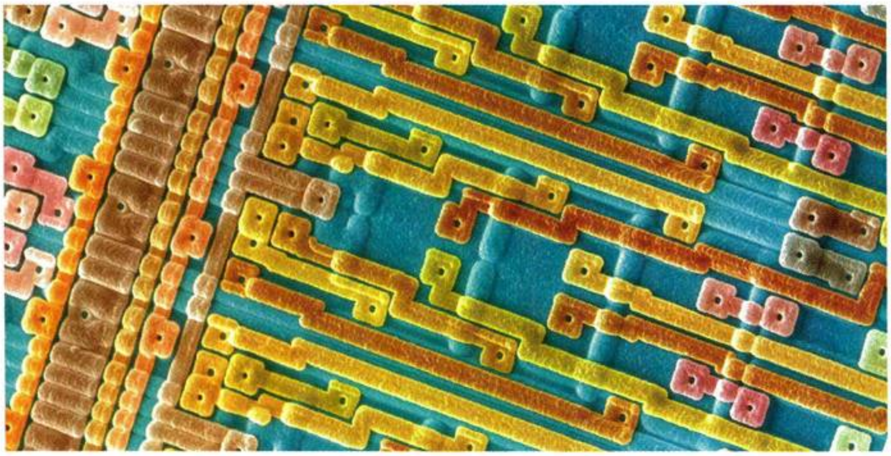
## sky Gem

# All that Remains

Sibling remnants of a bygone molecular cloud dance about the mammoth backlit lane of dust traversing the midsection of a Sagittarian oasis. Beyond the impressive display of photo-evaporated gas, Bok globules, knots, and pillars, however, this digital mosaic of the Lagoon Nebula (M8), testifies to the enormous influence new stars impose on their natal environs.

N. A. Sharp/NOAO/AURA/NSF

# Strange Indeed



**Working with entangled photons may help engineers to develop smaller, faster microchips.** A. Syred/Photo Researchers

I would like to congratulate Bob Berman for his essay "Quick Trip to Andromeda" (August 2001). In very simple words, he was able to combine relativity and the quantum weirdness of EPR correlations with the amazing most recent discoveries of Nicholas Gisin. Mr. Gisin's new experiments with the instantaneous "unison" behavior of widely separated photons may be difficult to understand, but may also give us hope for a powerful new weapon to help understand life's mysteries. — *John Kynigopoulos, Athens, Greece*

### Traveling with trepidation

I'm glad that Bonnie Bilyeu Gordon's trip to Zimbabwe, "Eclipsing Africa" (October 2001), and all of the June eclipse tours to Zimbabwe went well. But the mere fact that no political or legal problems occurred this year doesn't mean that one was wrong to have trepidation or even that one was right to go. The situation in Zimbabwe is not only deteriorating, but high officials are placing blame on certain classes of people. If anything were to go wrong while in Zimbabwe — if you were to be arrested for a traffic accident or for being too close to a squatter-related incident, for example — our government would have little or no leverage to help you. I'm glad everybody was lucky, but luck isn't the same as cautiousness or wisdom. — *Jay M. Pasachoff, Chair, Working Group on Eclipses of the International Union, Astronomy Department, Williams College, Williamstown, Massachusetts*

*This June, Pasachoff led a National Science Foundation and National Geographic Society-sponsored expedition of Williams College students and researchers to view the total solar eclipse in Lusaka, Zambia — just across the border from Zimbabwe.*

### Fishing for answers

I was a bit dismayed to find several errors in Paul Perry's article "Diving for Spacecraft" (October 2001). First of all, astronaut Gus Grissom was not "rescued only seconds before his vessel filled with water." According to official NASA reports, the hatch blew off, water began to spill into the spacecraft, and Grissom made a hasty exit. While he did escape into the "relative safety of the sea," Grissom was in danger of drowning because an open vent on his spacesuit began to fill with sea water. A horse-collar was lowered to rescue Grissom only after the spacecraft was cut loose and allowed to sink.

In addition, Grissom's flight was a suborbital shot. If the retrorockets had not fired, he would not have landed "almost anywhere, even in the densest jungle or steepest mountain range." He would have splashed down in the Atlantic anyway; the retrorockets were simply being tested for later manned orbital flights.

Lastly, the space shuttle *Challenger* exploded at 73 seconds, not "less than a minute into its flight." — *Jeffrey T. Iles, San Diego, California*

After reading "Diving for Spacecraft," I feel compelled to express disappointment with its content. I was troubled by the lack of any sort of exoneration for astronaut Gus Grissom. I saw the *Liberty Bell 7* in St. Louis, Missouri, in August. It was clear to me from the information presented at the St. Louis Science Center that any reasonable person would find Grissom not to have been at fault. — *David C. Clark, Saratoga, California*

### An erroneous circle of fifths

In the October 2001 edition of "Ask Astro," both William Schomaker and Chris Conselice suggest that our solar system is ⅕ of the way out from the galaxy's center. At a distance of approximately 25,000 light-years, this would make the diameter of the Milky Way Galaxy more than 250,000 light-years wide. I thought the Milky Way was approximately 100,000 light-years in diameter. — *Stephen Reiss, Imperial Beach, California*

*The diameter of the Milky Way Galaxy's visible disk is roughly 125,000 light-years across. Moreover, astronomers are confident that the sun lies about 25,000 light-years from the galaxy's center, or 40 percent (⅖) of the distance to the galaxy's edge. Regrettably, a simple typographical error was copied from one answer to the other. In both answers, the fraction should read ⅖ rather than ⅕.* — Astronomy *editors*

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**Please don't forget about . . .**
In reading Kelly Kizer Whitt's article "At the Head of their Class" (*Explore the Universe*, 8th Edition, 2002), I find that you have left out a very significant part of the astronomical world.

What happened during the 1,400 years between Ptolemy and Copernicus? This is where the Arab Muslim astronomers come to mind. During the Muslim expansion, education and science flourished for more than seven centuries. I would like to suggest some names like Muhammad Bin Musa Al-Khwarizmi (Algorizm) (770–840 A.D.), Thabit Ibn Qurrah (Thebit) (836–901 A.D.), Al-Razi (Rhazes) (864–930 A.D.), Al-Sufi (Azophi) (903–986 A.D.), Abu Raihan Al-Biruni (who determined Earth's circumference), Al-Zarqali (Arzachel, inventor of the Astrolabe), Ibn Rushd (Averroes) (1128–1198 A.D.), and Al-Bitruji (Alpetragius). — *Abdul Shukor, Singapore*

I was disappointed to find that you neglected to include Carl Sagan in your list of the top 25 astronomers of all time. How many others on that list worked as hard as Sagan did to bring science to the masses? Many professional astronomers have been so bold as to cast him aside as a mediocre scientist. Please, let's not follow their lead. After all, don't science magazines like yours owe much of their success to Sagan's pioneering work as science's premiere public relations guru? Without his help, I think you'd be hard pressed to sell more than a thousand copies per month. — *Peter Moody, Tucson, Arizona*

**Correction**
A photo of Mars appearing in the "2002 Guide to the Sky" (*Explore the Universe*, 8th Edition, page 51) was mistakenly credited to John Chumack. The image should have been credited to António José Cidadáo.

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# Making Black Holes in the Lab

▶ During World War II, Manhattan Project scientists speculated that the detonation of an atomic bomb might ignite the atmosphere, sparking a global conflagration that would extinguish life on Earth. Later calculations and tests, however, proved such concerns to be unfounded.

Similarly, the idea of creating black holes in a laboratory might sound like a Doomsday scenario. After all, wouldn't a black hole start gobbling up everything in its vicinity like a Pac Man gone berserk, eventually swallowing the entire Earth?

According to new calculations by a team of physicists, black holes might become standard fare at Europe's CERN particle accelerator near Geneva, Switzerland. According to the calculations, the upgraded Large Hadron Collider (LHC) at CERN could produce as many as one black hole every second once the accelerator is up and running around 2007.

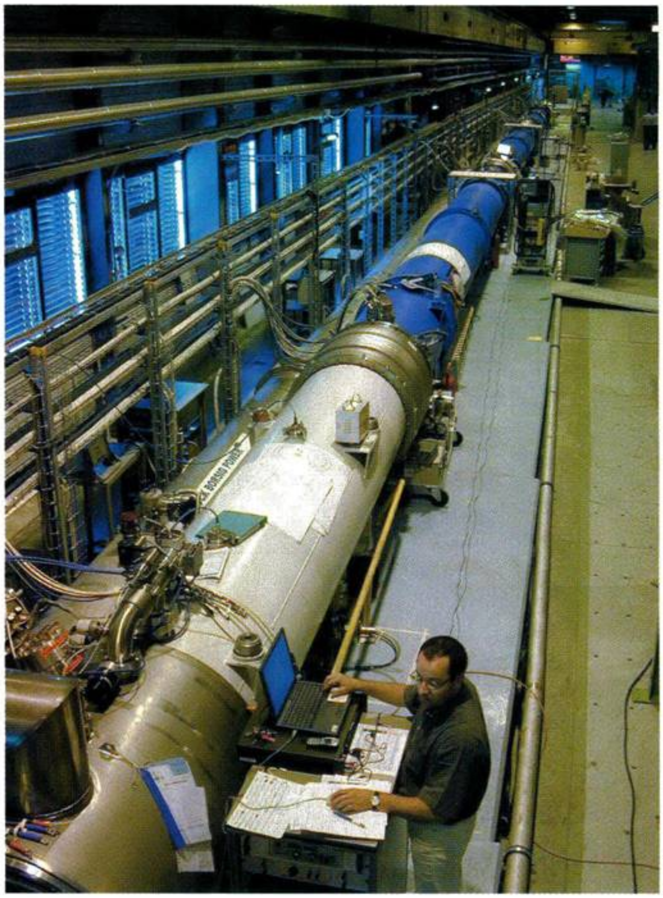
"It is possible that the LHC and future accelerators will become black hole factories," says Greg Landsberg of Brown University, who along with colleague Savas Dimopoulos of Stanford University published his predictions in the October 15 *Physical Review Letters.*

At the LHC, experimenters will slam together beams of protons traveling at close to the speed of light. Some of the stupendous energy of these collisions will be converted into massive elementary particles according to Einstein's famous equation $E=mc^2$, which states that energy can be converted into mass, and vice-versa. The LHC's collisions will be so violent that they will create particles that haven't existed in the universe since a trillionth of a second after the Big Bang. But according to Landsberg's team, the LHC will also produce particles in such a small volume of space with such ferocity that it will produce miniature black holes a thousand times smaller in size than an atomic nucleus. That is if — and this is a big if — gravity is a stronger force than scientists currently believe.

If the universe contains extra spatial dimensions beyond the three that we experience in our everyday lives, gravity might operate in these extra dimensions as well. Consequently, extra dimensions will dilute the strength of gravity, just as extra water will dilute a glass of iced tea. Because particle accelerators built before the LHC have been unable to create enough energy to open up these hidden dimensions, scientists have only been able to hypothesize their existence. If extra dimensions do exist, however, the LHC will be powerful enough to probe them, generating mini black holes in the process.

Before you go out spending your life's savings, figuring the world will end in 2007, note that about 100 times per year cosmic rays slam into Earth's atmosphere with enough energy to create mini black holes. Yet these black holes quickly evaporate into a stream of elementary particles known as Hawking radiation, after the celebrated British physicist Stephen Hawking, who first predicted black hole evaporation in the early 1970s.

Similarly, the LHC's black holes will also spontaneously evaporate so quickly (in $10^{-26}$ second) that they won't have time to gobble up any surrounding material. "The very fact that cosmic rays have not made us extinct in the billions of years of Earth's existence is the best proof that the LHC is completely safe to operate," says Landsberg.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**Toxic waste? Laboratory-made black holes could become a bona fide reality before the decade is out.**

If CERN physicists are eventually able to detect Hawking radiation from mini black holes, the discovery will pave the way for the unification of the twin pillars of 20th century physics — Einstein's general theory of relativity and quantum mechanics — while at the same time revealing the nature of any extra hidden dimensions. — ROBERT NAEYE, ASTRONOMICAL SOCIETY OF THE PACIFIC

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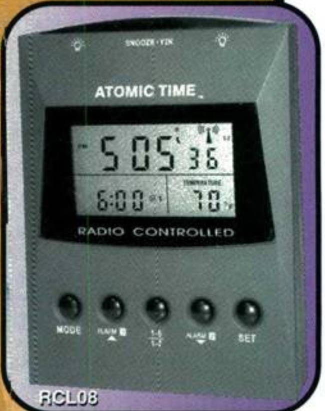
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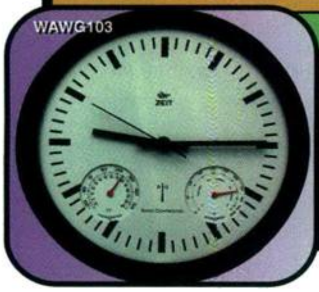
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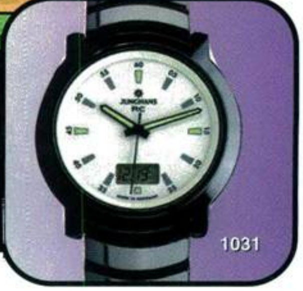
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If you want the right telescope, you need more than a camera store clerk armed with only a price list and not a clue in the world about astronomy.

What you *really* need are people who will take the time to listen to what *you* need, people who can answer your questions, people with years of experience using and selling telescopes who can help you get the most telescope for your dollar. That's exactly the kind of people you'll find at ***astronomics***.

Unlike camera stores and shopping mall gift shops, telescopes are our specialty at ***astronomics***, not just a sideline. We're a family-owned full-line telescope dealer – not just a few toy telescopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. And, unlike department store clerks, we don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

We've been helping people choose the right telescope since 1979. We have the experience to help *you* pick the scope that fits your needs . . . *and your budget* . . . from the many Meade, Celestron, TeleVue, Takahashi, and Questar telescopes we stock at discount prices from $99 to $27,995.

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## We have the Meade LX90 in stock!

You can live the good life of big-aperture go-to full-featured fully computerized astronomy for not much money with the 8" **Meade LX90** Schmidt-Cassegrain.

The LX90 is only $1695, including an adjustable height field tripod and a go-to Autostar computer with 30,223 stars and objects in its data base.

We've shipped hundreds of these scopes to delighted customers. With 250 scopes scheduled for delivery before the end of the year (and we had 25 in stock as this was written on 10/1), chances are good you can get *your* LX90 with little or no delay. While short backorders *are* possible on this hot new scope, if Meade is shipping the LX90 for a dealer to keep in stock, chances are good we *have* it in stock.

Meade prices are about the same anywhere you call. So why order a Meade scope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade you want . . . right now . . . at the right price . . . right here at ***astronomics.***

Meade 8" LX90
**$1695**

## The new Meade GPS scopes. You do the looking. They do the work!

Never before have so many features been packed into one telescope series. And never before have go-to scopes been so easy to use. The new LX200 GPS scopes – the widest variety of go-to scopes on Earth – have just about all the features you've been dreaming about since you started astronomy.

Fully automatic GPS alignment, including true north and true level sensors and automatic magnetic declination correction that's unavailable in competitive scopes; mirror lock to eliminate image shift when using the built-in 4-speed electric focuser; a database of over 125,000 stars and objects; flashlight battery operation; and so much more. The Meade GPS scopes are designed to let you spend more time looking *at* celestial objects and less time looking *for* them. And isn't that what you want out of a telescope? With literally hundreds on order as of 10/1, we probably have your Meade GPS scope waiting for you.

Meade 8" LX200GPS
**$2495**

## A baby light bucket for cool fall viewing . . . at a cool $149⁹⁵.

The **Bushnell Voyager** 4.5" tabletop rich field reflector gives you a wide field of view, plus all the light-gathering power you can get from a tabletop scope.

Comes with shoulder strap, two eyepieces for 19x and 100x, and a 3-leg tabletop base that also mounts on any photo tripod for use in the field. The Voyager is a good scope for the beginning astronomer, as well as a great travel scope for the more experienced observer.

4.5" Voyager
**$149⁹⁵**

## Meade LXD55 scopes make other reflectors and refractors obsolete!

For little more than the cost of an ordinary equatorial refractor or reflector, you can get a fully computerized Meade LXD55. The go-to capability of the LXD55 series is the most significant advance in an affordable German equatorial mount since its invention in the early 1800s!

You don't have to spend your time hunting for faint deep space objects with a 5" or 6" LXD55 refractor or 6" to 10" Schmidt-Newtonian reflector. A few touches on the keypad of the built-in Autostar computer will send the scope speeding to any of more than 30,000 stars and objects, center it on the object, and track it while you observe at your leisure. For many people, star hopping will become obsolete. You'll spend more time looking *at* deep space objects and planets and less time looking *for* them with an LXD55.

Full scope details are on our website and in Meade's ads in this magazine. Scopes are scheduled to start shipping in December. Get on our waiting list so you can be one of the first to get your observing out of the 1800s.

Meade 5" LXD55
**$695**

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**$729**

## We stock Pentax XL eyepieces from $227⁵⁰.

From 5.2mm to 40mm, we stock all the Pentax wide field (55° to 65°) XL eyepieces. Each has a rotate-to-adjust-the-eye-relief eyecup, ED glass, and a long 20mm eye relief that's perfect for those who wear eyeglasses. We also stock the 8-24mm Pentax zoom.

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## $50-$100 rebates on image-stabilized Canon binoculars through 1/3

"Truly a quantum leap in binocular observing . . . particularly impressive was how well these binoculars compared to much larger apertures . . ." is what *Sky & Telescope* said about the Canon image-stabilized binoculars. There are no jittery images while handholding these high power binos, just rock-solid observing that reveals more detail than conventional binoculars. From a 10 x 30mm to a big 18 x 50mm, there's an image-stabilized Canon that's right for you . . . and Canon has new lower prices, too, plus a $50 to $100 rebate. You'll find the details on our website.

Canon

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# We'll sell you the *right* telescope.

## Last chance for holiday gift-giving!

Here are some sale-priced binos, books, and accessories that make excellent holiday gifts, for both giving and getting. Take a look . . .

### Half-price observing books!

We bought almost 4000 deep sky observing books from Astronomy Magazine, at some very special prices that we're passing on to you. They make super stocking stuffers, since we've priced them as much as 50% below normal retail.

**Beginner's Guide to Amateur Astronomy,** 166 pages, softbound; a great book on how to get the most from any new scope; reg. $14.95 ...... **$\$9^{95}$**

**Galaxies & The Universe** 112 pages, softbound; photos, descriptions, and finder charts help you find hundreds of galaxies, reg. $19.95 ...... **$\$9^{95}$**

**Stars & Galaxies** 200 pages, hardbound; photos, descriptions, and finder charts help you find 344 superb deep sky objects, reg. $29.95 ...... **$\$14^{95}$**

**Universe From Your Backyard** 188 pages, hardbound; constellation by constellation tour of 690 deep sky objects, reg. $29.95 ........... **$\$14^{95}$**

### Meade $\$69^{95}$ bino bargain!

We bought 650 Meade 8 x 42mm Safari Pro binoculars that we're selling for about *half regular dealer cost.*

Armored, multicoated, BaK4 porro prisms. 8.2° field, 15mm eye relief, 5.25mm exit pupil, soft case, lifetime Meade warranty. Super for birding, sports, astronomy. Less than 200 still available. ~~$285~~ **$\$69^{95}$**

### Rare bird indeed . . . a $450 Audubon-endorsed binocular for only $\$179^{95}$!

We bought 400 of these National Audubon Society-endorsed Celestron/Tasco Bald Eagle 8 x 42mm Rare Bird Series roof prism binoculars. We got them at a such a good price that we're able to sell them for *$70 below regular dealer cost.*

These are the best $180 binos we've ever looked through. Armored, waterproof and fogproof, multicoated, BaK4 prisms, soft case and a wide comfort neck strap. A 6.6° field, good 16mm eye relief, and a ***No-Fault*** lifetime warranty. If anything ever goes wrong them, even if you drop them, they'll be repaired or replaced for free!

## The 8" and 11" NexStar GPS are available from stock!

NexStar 11 GPS

**$2999**

Finding your way around the night sky is a lot easier than it used to be. Celestron's computerized go-to scopes – the 11" **NexStar 11 GPS** at $2999 and the 8" **NexStar 8 GPS** at $2499 – were the first to use a built-in electronic compass and GPS (Global Positioning System) satellites to tell them where they are in time and space, align them on the sky, and start finding over 40,000 deep sky objects for you . . . *virtually automatically!*

For CCD astrophotography, both scopes have Fastar-compatible optics that you can convert to ultra-fast f/1.9 and f/2.1 focal ratios for wide field images. With an optional Fastar lens and a $1295 SBIG ST-237A CCD camera, the 8" GPS will record an astonishing 32 x 42 arc minute field – over three times the area of a $7695 CCD camera on the same scope without Fastar! *No other GPS scopes have Fastar optics!*

NexStar 8 GPS **$2499**

## Celestron rebates drop go-to scopes to their lowest prices ever! Only $1399 for an 8" . . .

NexStar 8

**$1399**
after $100 mail-in rebate

$50 to $100 mail-in rebates direct from Celestron through Jan. 10 make these Celestron computerized scopes more affordable than ever before. A $100 rebate puts the price of this big 8" aperture **Celestron NexStar 8** go-to SCT within the reach of almost everyone! It comes with an adjustable height tripod, Starbright multicoated optics, red dot finder, 40mm Plössl eyepiece, and a computer with 18,000+ objects in its memory. It's enough telescope to keep you busy observing for the rest of your life!

### $1099 for a 5" . . .

NexStar 5

CELESTRON

You get a $149 value NexStar adjustable height aluminum tripod and equatorial wedge *for free* when you buy a **Celestron NexStar 5** go-to 5" Schmidt-Cassegrain. And, after the $50 mail-in rebate from Celestron, this limited time $1099 price is Celestron's lowest ever for a 5" go-to scope! NASA uses 5" Celestron optics on the Space Shuttle. Doesn't your observing deserve the same image quality?

**$1099** after $50 mail-in rebate

### $549 for a 4" . . .

NexStar 4

**$549** after $50 mail-in rebate

The 4000-object computer of the new **Celestron NexStar 4** go-to Maksutov-Cassegrain is standard equipment, not an option as it is with some scopes. The computer hand control can be used even when docked conveniently in the scope's sleek single fork arm mount. A long eye relief Star Pointer red dot finder makes aligning on the skies a snap. The AA battery-operated tabletop NexStar 4 is so easy to use that you'll be observing only minutes after you take it out of the box. And the $50 Celestron-direct rebate makes it easier than ever to get into astronomy.

## We have over 25 tons of telescopes in stock!

We generally keep well over 1000 telescopes in stock. At an average weight of 50 lbs. and up, that means we usually have well over 25 tons of telescopes in inventory at any given time. We don't know of many dealers – if any – who stock telescopes in those quantities . . . *no matter what they claim.* But we do. And we don't just stock telescopes in large quantities. We have literally tons of accessories, as well. Eyepieces, filters, CCD cameras, dew caps, Barlows, off-axis guiders, electric focusers, T-adapters, tele-extenders, counterweights, and much more.

## TeleVue? We keep it in stock.

TV-85 **$2080**

Whether it's the newest scope or the newest eyepiece, if it's a TeleVue, the chances are good we have it in stock. Gibraltar, Panoramic, and TelePod altazimuth mounts; Nagler, Radian, Panoptic, and Plössl eyepieces; Powermates and Barlows; red dot finders; star diagonals; 35mm and digital camera adapters; and even more – if it's from TeleVue, we probably have it.

## Sell your used telescopes and accessories through the *free* classified ads at www.astrofieds.com

> You guys are great! Thank you very much. Will buy my next telescope from you for sure. Rate your service and customer relations A+++.
>
> **Customer Quote of the Month #118**

## Celestron rebates put 650 go-to scopes at their lowest prices ever!

**$274**
after $25 mail-in rebate

NexStar 114

We bought over 650 computerized go-to Celestron NexStar scopes at great prices, and we've been passing our savings on to you. Through Jan. 10, Celestron's factory-direct rebates make them an even better buy!

You get two 1.25" eyepieces, a red dot finder, dual DC motor drives with pushbutton hand control, software that can control the scope from a computer, an adjustable height metal tripod with accessory tray, *and* a separate computer hand control for full go-to operation. Both telescopes are so sensationally easy to assemble and use that you'll be observing in minutes.

A review in *Astronomy* said, "What fun to press "M31" on the hand control, then watch as the Andromeda Galaxy slides into the field of view! . . . a great telescope for someone as young as 12 or 13."

The **NexStar 114**, left, is a 4.5" aperture f/9 reflector. The **NexStar 80**, right, is a limited quantity 80mm f/5 rich field refractor. Both scopes make go-to computerized astronomy amazingly affordable.

**$254**
after $15 mail-in rebate

NexStar 80

## We stock Losmandy mounts.

If you're looking for a premium quality German equatorial mount, look no further than the Losmandy GM-8 and G-11 mounts we stock. Dual axis drives with PEC electronics, adjustable height tripods, go-to optional, and more.

Losmandy G-11

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*NEAR MISSION*

# NEAR Impacts Eros's History

Since the Near Earth Asteroid Rendezvous (NEAR-Shoemaker) spacecraft began snapping close-ups of 433 Eros last year, planetary scientists have puzzled over the origin of the large boulders that dot the asteroid's surface. In the September 27 issue of *Nature*, a team of scientists suggests that most of the large boulders on Eros were created by a single impact.

The 21-mile-long asteroid is more than four billion years old and is itself a likely fragment of an even larger asteroid split apart by a collision. Perhaps a billion years ago, a small comet or small asteroid collided with Eros to blast a crater that is nearly five miles (7.6 kilometers) wide.

Located near one end of the potato-shaped asteroid, the crater is provisionally called Shoemaker, after geologist Eugene Shoemaker, who loved to investigate such astronomical impacts.

Using software that counted and sized craters in NEAR-Shoemaker images, Cornell University researcher Peter Thomas counted about 30,000 rocks scattered over the 434 square miles (1,125 square km) of Eros's surface. Of these, 6,760 rocks are larger than about 16 yards (15 meters) across. Thomas and his colleagues found that 44 percent of these boulders lie inside the Shoemaker crater. Moreover, the team also believes that most of the large boulders along the asteroid's equator were ejected from Shoemaker.

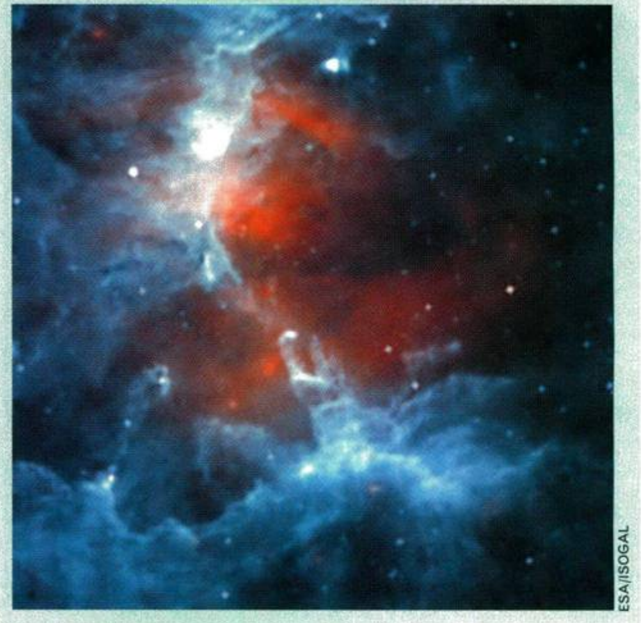
"We know they came from Shoemaker because the mapping of the geography of the pattern [of the rocks] on the surface closely matches the predicted paths from the one impact event that made Shoemaker," Thomas says.

Yet, if most of the asteroid's boulders were ejected by the impact that created Shoemaker, another question emerges. Why weren't many of the large boulders also thrown out by the impacts that created Eros's two other large craters, Himeros and Psyche? Thomas guesses that those rocks may have been buried, were eroded, or were never created in the first place. — Vanessa Thomas

**A NEAR flyby of the crater Shoemaker has fueled speculation that most of the boulders on 433 Eros originated from this impact site.**

NEAR Imaging Team

**INFRARED SPACE OBSERVATORY**



ESA/ISOGAL

**AN ICY VEIL ENSHROUDS fire in the Eagle Nebula (M16), 7,000 light-years from Earth. The emission nebula is an active stellar nursery containing cold clouds of dust — a necessity for successful star birth. If the environment is too warm, outward thermal pressure prevents gravity from pressing atoms against each other tightly enough to initiate nuclear fusion. Only an infrared observatory like the European Space Agency's Infrared Space Observatory (ISO) could detect these frigid, –100° Celsius (–150° F) clouds. ISO captured this striking look at the Eagle's temperature clash before the spacecraft was decommissioned in May 1998.**

*X-RAY ASTRONOMY*

# Astronomers Find Chilly Star

When you're hot, you're hot, and when you're not . . . well, it makes a handful of astronomers wonder, especially if you're a tiny neutron star that has remained relatively frigid for more than a decade, despite the never-ending, daily assault of thermonuclear explosions more powerful than one billion atom bombs.

An international team of scientists led by MIT astrophysicist Rudi Wijnands has used NASA's Chandra X-ray Observatory to keep close tabs on the famously pounded, yet seemingly heat-resistant, neutron star KS 1731–260, found near the center of the Milky Way Galaxy.

Neutron stars are the core remnants of stars that shed their layers in violent supernova explosions. Typically, they are no larger in diameter than a few miles but are so dense that their gravity will rip material —

# Introducing The New Celestron 14" GOTO Telescope.

Get a good look at Celestron's new CM1400 14" GOTO telescope, quite possibly the most powerful personal use stargazing instrument in the universe. By combining advanced features like the NexStar® GOTO control system with the largest aperture Celestron® offers, we created a telescope with unparalleled optics and ease of use. The already sophisticated CI-700 mount becomes an even bigger joy to use now that it works in tandem with the GOTO's computerized database. And like all advanced series telescopes, the precision optics work together to provide spectacular views that you simply can't get with other telescopes. ● To learn more about Celestron's new 14" GOTO telescope, call 310-328-9560, or visit our website (www.celestron.com) to find a dealer near you.

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## FEATURES & SPECIFICATIONS

**SOFTWARE:**
- 40,000+ object database. Stores numerous user-defined objects.

**ELECTRONICS:**
- Computerized hand control with easy-to-read backlit liquid crystal display (LCD) unit
- Permanent Periodic Error Correction (PPEC) – once periodic errors are recorded for elimination, the telescope maintains the recording even when turned off
- Built-in, adjustable backlash compensation
- AutoGuider Port
- RS-232 port for communication with a PC to operate and use with the telescope (one on hand control and one on drive base)

**MECHANICAL**
- 5.625" diameter precision bronze gear, 180-tooth
- .4375" diameter precision 303 stainless steel worm gear

**OPTICS**
- Fastar compatible for f/2 CCD Imaging
- 14" (355.6mm) large aperture Schmidt-Cassegrain optical system
- Focal length of 3910mm at f/11
- Resolution: .33 arc seconds
- Starbright™ Coatings
- Hand-figured optics

**WEIGHT** • 164 pounds

**ACCESSORIES (STANDARD)**
- 40mm multi-coated 1.25" Plössl eyepiece (98X)
- 9x50 Finderscope
- Car Battery Adapter
- 2" star diagonal with 1.25" adapter
- Heavy duty CI-700 mount
- Heavy duty tripod

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- Reducer/Corrector f/6.3
- AC Adapter
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mainly gas — away from companion stars that drift too close. This process, called accretion, leads to the collection of hot gas onto the neutron star's surface, an event so highly energetic that the degenerate star heats up and glows in x rays.

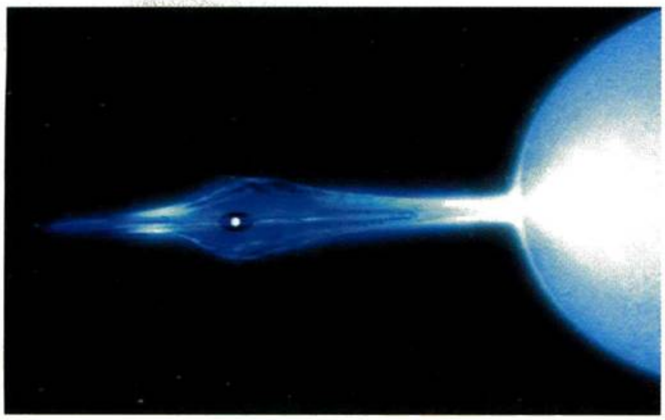
Binary systems containing neutron stars like KS 1731–260 are known to cycle between periods of low and high accretion, corresponding to periods of relative cool and intense heating. They are most detectable during more active accretion. Despite just coming out of a very recent 12-year period of active bombardment, KS 1731–260 remains remarkably chilly.

"Twelve years of constant bombardment: One would think that would heat things up," says Wijnands. "This leaves us wondering whether some neutron stars are in the freezer for a much longer time than previously thought and consequently take a long time to heat up, or whether they cool down incredibly fast. Either explanation has profound implications for our field."

Based on the currently most-accepted theory of neutron star heating and cooling, Wijnand's team calculated that KS 1731–260 must have been in a low accretion phase for over a thousand years to remain so cold in the face of 12 years of thermonuclear fury.

Until now, however, no neutron star has exhibited such prolonged dormancy. In fact, the closest rival to this thousand-year mark of quiescence has only been a relatively brief interval of 100 years or so.

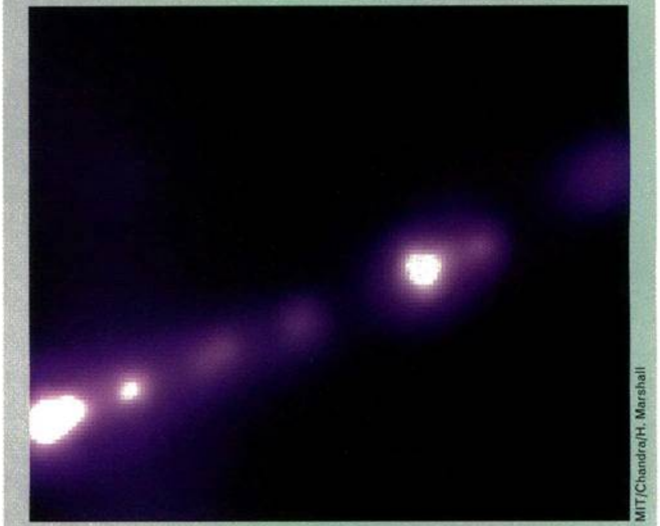
To help explain this apparent mismatch between theory and reality, as well as to possibly construct an entirely new model, Wijnand's team will soon employ Chandra in a much larger survey of binary systems going through various phases of high, low, or zero accretion. — PAUL MORLEDGE



NASA

**The powerful gravitational pull of a tiny, but dense, neutron star (KS 1731–260) causes material to flow from its companion star.**

**CHANDRA X-RAY OBSERVATORY**



MIT/Chandra/H. Marshall

**HIGH-SPEED GLOWING JETS TWIST AWAY from the center of the elliptical galaxy M87 in the constellation Virgo (brightest blob at left). This Chandra X-Ray Observatory image reveals an irregular, knotty structure in the jet, which is produced in a slingshot effect as material falls into the galaxy's central black hole. The highly energized matter, escaping the black hole's tug, speeds away from the galaxy's center at super high velocities through a strong magnetic field. The resulting glow comes from so-called synchrotron radiation, caused by charged particles that fluoresce in radio, visible light, and x-ray wavelengths. Chandra data suggest that the energy streaming from the galaxy's central knot is not coming from material falling into the black hole, but probably from unresolved knots of matter nearby.**

*PLANETARY SCIENCE*

# Dust Storm Grasps Mars

▶ In late June, a dust storm began raging across the Red Planet. But this wasn't just any dust storm — it became so immense that it prompted amazed astronomers to dub it "the perfect storm." Now, thanks to the 20/20 vision of two veteran NASA spacecraft — the Mars Global Surveyor and the Hubble Space Telescope — scientists around the world have been given front-row seats to view this phenomena as never before.

"This is an opportunity of a lifetime," explains Hubble observer James Bell of Cornell University in Ithaca, New York. "We have a phenomenal, unprecedented view from these two spacecraft."

The rare martian storm kicked up a cloud of dust large enough to engulf the entire planet and initiate dramatic effects. As the sun warmed the airborne dust particles, Mars's upper atmospheric temperature increased by about 80° Fahrenheit. At the same time, however, the surface of the planet chilled precipitously due to the constant veil of dust.

Both spacecraft have given astronomers clues to understanding Mars's unique climate. While Hubble does not view Mars continuously, it can capture most of the planet in one snapshot, showing the full

# 3,426 Stars. 618 Celestial Phenomena. 28 Moons and Planets. One Button.

**NEXSTAR 60GT**

$249.00
suggested retail price

- 60mm [2.4"] diameter
- 700mm focal length [f/12]
- Starpointer™ finderscope
- 20mm [35x], 10mm [70x], and 4mm [175x] MA eyepieces
- 1.25" star diagonal
- Hand control with 4,000 object database
- Includes sturdy metal tripod

**NEXSTAR 80GT**

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- 80mm [3.1"] diameter
- 400mm focal length [f/5]
- Starpointer™ finderscope
- 25mm [16x], 10mm [40x] eyepieces
- 1.25" star diagonal
- Hand control with 4,000 object database
- Includes sturdy metal tripod

**NEXSTAR 114GT**

$439.00
suggested retail price

- 114mm [4.5"] diameter
- 1000mm focal length [f/9]
- Starpointer™ finderscope
- 25mm [40x], 10mm [100x] SMA eyepieces
- 1.25" star diagonal
- Hand control with 4,000 object database
- Includes sturdy metal tripod

Celestron's NexStar™ telescopes are so simple to operate, practically anyone can be set up and stargazing within minutes of taking one out of the box. That's because each comes with a pre-programmed database containing the coordinates for thousands of spectacular celestial sights. ● Thanks to this incredible GOTO technology, all you have to know is where you are, what time it is, and the date. Then choose what you want to see and the NexStar seeks it out. ● With a wide variety of powers and price points, plus the smart engineering and precise optics you can only get from Celestron, you're sure to find a NexStar that's just right for you.

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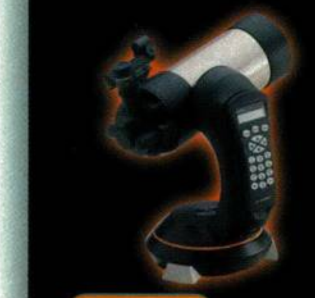


**NEXSTAR 4**

$599.00
suggested retail price

- 4" Maksutov-Cassegrain optics
- 1,325mm focal length [f/13]
- Starpointer™ finderscope
- 25mm [53x] SMA eyepiece
- Hand control with 4,000 object database
- 1.25" star diagonal with flip mirror system
- Optional tripod available

**NEXSTAR 5**

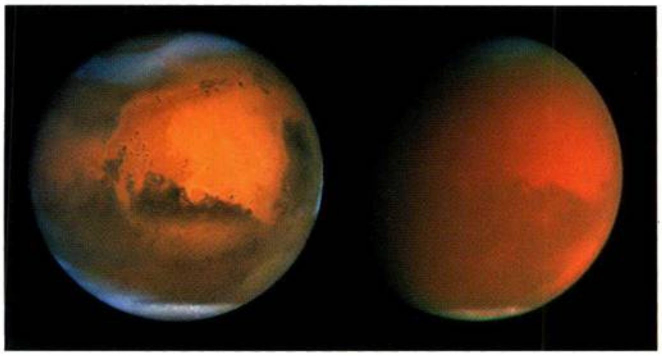
$1149.00
suggested retail price

- 5" Schmidt-Cassegrain optics
- 1,250mm focal length [f/10]
- Starbright™ multicoatings
- Starpointer™ finderscope
- 25mm [50x] Plössl eyepiece
- 1.25" star diagonal
- Hand control with 18,000 object database
- Includes tripod and AC adapter

**NEXSTAR 8**

$1499.00
suggested retail price

- 8" Schmidt-Cassegrain optics
- 2,032mm focal length [f/10]
- Starbright™ multicoatings
- Starpointer™ finderscope
- 40mm [51x] Plössl eyepiece
- 1.25" star diagonal
- Hand control with 18,000 object database
- Includes tripod and AC adapter



NASA/Hubble Heritage Team/J. Bell, M. Wolff

**From June (left) to September (right), a springtime dust storm engulfed Mars. It's the largest storm seen in recent decades.**

range of dust activity from sunrise to sunset. And thanks to the Mars Global Surveyor, scientists can study the storm and its daily effects on the planet.

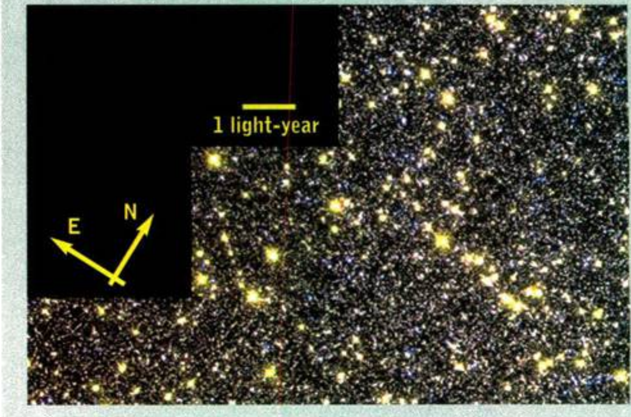
Using the MGS Mars Orbiter Camera, planetary scientists continuously photograph Mars. As a result, they have been able to pinpoint the locations where dust is being raised, and observe how it interacts with other weather phenomena and surface topography of the arid, dusty planet.

"What we have learned is that this is not a single, continuing storm, but rather a planet-wide series of events that were triggered in and around the Hellas Basin," explains Mike Malin of Malin Space Science Systems, Inc., lead investigator on the orbiter camera. "What began as a local event stimulated separate storms many thousands of kilometers apart." In addition, MGS's Thermal Emission Spectrometer has traced the amount and location of dust in the atmosphere by measuring temperature changes.

The storm — brewing for four months now as this issue goes to press — has also been closely watched by the team operating the 2001 Mars Odyssey spacecraft, which successfully rendezvoused with the Red Planet on October 23.

"Understanding global dust storms is a vital part of the science goals of the Mars Exploration Program," stresses James Garvin, NASA's lead scientist for Mars Exploration. "Such extreme climate events could potentially provide clues to how climate changes operate on Mars — now and in the past — as well as provide linkages to the record of sediments on the planet." — Elesa Janke

HUBBLE SPACE TELESCOPE



NASA/Hubble Heritage Team/SFSU/A. Cool

**THE HEART OF A STAR CLUSTER RESOLVES into myriad suns scattered so thickly they are nearly uncountable. This Hubble Space Telescope Heritage image shows the most densely packed portion of Omega Centauri, the largest and brightest globular cluster in the Milky Way Galaxy. Some 17,000 light-years from Earth, Omega Centauri is a favorite treat for summer stargazers; its several million aged suns make it valuable for researchers too. The stars of Omega Centauri are packed so closely together that ground-based telescopes struggle with separating them. Hubble's remarkable resolution from space, however, captures many distinct points from individual stars right across the cluster's face.**

*DEEP SPACE 1 MISSION*

# NASA Catches Comet Borrelly

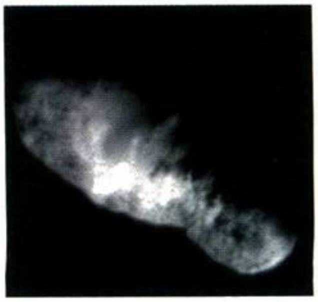
▶ On September 22, NASA's Deep Space 1 spacecraft passed within 1,400 miles (2,200 kilometers) of the rock-ice nucleus of Comet Borrelly. The aging craft sent black-and-white images of the inner core, along with information about gaseous composition, infrared emission, and the comet's interaction with the sun's continually flowing wind of charged particles.

Around the globe, earthbound telescopes also joined to race to observe Comet Borrelly's encounter with Deep Space 1. Astronomers at Kitt Peak National Observatory in Arizona, as well as others in California and Hawaii, captured wide-field images of the comet's dust tail and coma in order to aid future interpretation of images from Deep Space 1.

Not surprisingly, Comet Borrelly bucked at least one of the Deep Space 1 team's pre-encounter expectations. Team members, like University of Michigan astronomer David Young, expected that the comet's nucleus would be found at the center of the cloud of gas and dust surrounding the nucleus. They also believed that the solar wind should flow symmetrically about this coma.

To their relief, the team has found the solar wind's flow to be symmetric. But on closer inspection, they also find the nucleus to be slightly off-center, spewing a lopsided jet of coma-forming material. "Most of the charged particles are formed to one side, which is not

**Lit from below by the sun, the five-mile-wide Borrelly nucleus displays a variety of terrain features.**



NASA/JPL

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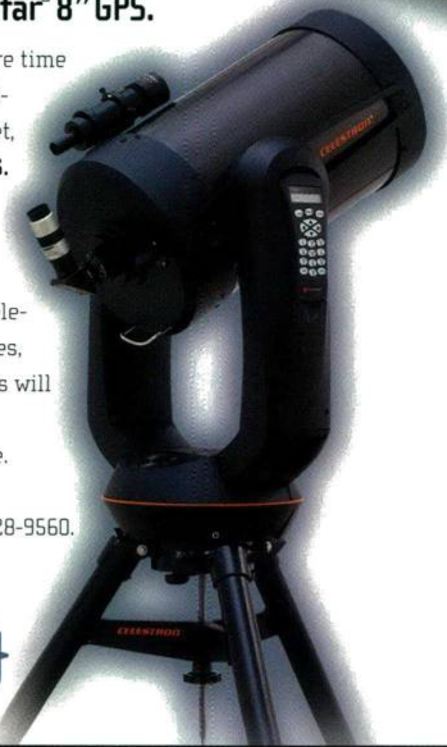

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FIND OUT MORE ABOUT OUR OTHER EXCEPTIONAL TELESCOPES AND OPTICAL GEAR, AND NEARBY DEALERS. (310) 328-9560 • www.celestron.com what we expected," says Young. Through further analysis, they hope to understand Comet Borrelly's unexpected behavior.

Deep Space 1 was launched in October 1998 as part of NASA's New Millennium program. Its primary mission — to test the merits of ion propulsion and several other new technologies — was completed in September 1999. Though Deep Space 1 was never designed to encounter a comet, NASA extended the craft's mission in order to capitalize on this opportunity to catch up with Comet Borrelly. — W. B. SCHOMAKER

SOLAR ASTRONOMY

## Onward Ulysses

▶ Eleven years ago, the intrepid Ulysses spacecraft (a joint venture between NASA and ESA) embarked on an odyssey to uncover the secrets of the sun. And on October 13, it passed over the sun's north pole for the second time since departing from the space shuttle *Discovery* in 1990. What's more, as Ulysses peered down on the plane of the solar system, all signs point to a star that's beginning to enter a periodic lull of sunspot and flare activity.

With the unflappable hero of Greek legend for its namesake, Ulysses was designed to observe the sun's heliosphere in order to understand the sun's 11-year cycle of activity and its subsequent impact on the solar system. To that end, designers selected Ulysses's gravity-assisted orbit to bring the craft over the poles of the sun, giving astronomers a unique view of the sun from outside of the ecliptic. Consequently, the spacecraft travels in a six-year orbit that brings it both near and far from the sun — from about 93 million miles to nearly 500 million miles (about five times the Earth-sun distance).

Ulysses' first pass of the north solar pole occurred in 1995, as the sun was at a minimum of activity. As Ulysses loomed high over the pole in October, however, the sun was just coming off a periodic spell of increased activity, offering a new observing experience for the craft.

Ulysses's researchers reported evidence that the sun's wind is picking up speed over the north solar pole. While the effect hasn't yet transferred south, the astronomers are confident that it soon will. "There may be turmoil yet near the equatorial region, but Ulysses has started observing conditions, which will eventually prevail all around the sun," says Andre Balogh of Imperial College of London and principal investigator for the Ulysses magnetometer.

Much of the sun's cyclical activity can be explained by a regular magnetic reversal that occurs every 11 years. When the magnetic poles on the sun begin to flip, its field becomes jumbled and leads to increased solar activity. These conditions, including a slower solar wind, define what astronomers call solar maximum. On the other hand, solar minimum is usually characterized by fast, hot outflows from voids in the sun's outer atmosphere. The new Ulysses observations show that the sun's magnetic field has flipped and that solar minimum is fast approaching. — W. B. S.

## Nature's Building Block Said Found

The space-bound eye of Hubble, the massive twin Keck telescopes in Hawaii, and a cosmic gravity lens two billion light-years away recently conspired to capture a relic of our cosmic past. Caltech astronomer Richard Ellis and a team of his collaborators announced in October that they've discovered an object that's so old and so far away, it predates the formation of galaxies. At 13.4 billion light-years away, the newly discovered protogalaxy appears to contain a mere few million times the mass of the sun and spans just 500 light-years across. This stands in stark contrast to, for instance, galaxies like the Milky Way, which may be a million times more massive and several hundred thousand light-years across.

NASA/ESA/A. Fruchter

**Galaxy cluster Abell 2218 magnifies a protogalaxy's light by 30 times.**

## Institutionalized Surfing

The National Science Foundation has awarded Penn State University with a multi-million-dollar, multi-year grant to establish the Center for Gravitational Wave Physics. The center will boast an interdisciplinary team of scientists from the university and other institutions in the United States, Canada, Scotland, and Germany. Researchers will probe the nature of gravitational waves generated by the most massive objects and violent events in the universe. They hope to work on an expected treasure trove of data to begin pouring in next year from gravitational-wave detectors in the United States, Europe, and Japan, in addition to a space-based detector that is planned for launch later this decade.

## Mirror Makeovers

Researchers working with the National Reconnaissance Organization (NRO) and the University of Arizona's Optical Sciences Center and Steward Observatory have constructed an ultra-thin, ultra-lightweight, active mirror that may revolutionize the next generation of space telescopes and satellites. Working from a design intended for the Next Generation Space Telescope, scheduled to replace Hubble later this decade, Optical Sciences Center scientist David Baiocchi and his colleagues recently created the 21-inch NRO demonstration mirror. The aluminum-coated mirror is only one millimeter thick, weighs just 2.2 pounds, and is supported by 31 tiny computer controlled actuators, weighing less than ⅕ ounce each. If the mirror were stretched over the length of an American football field, the difference between its highest and lowest points would be less than the thickness of two human hairs. Gravity — which will diminish in Earth orbit — currently generates the mirror's largest source of error.

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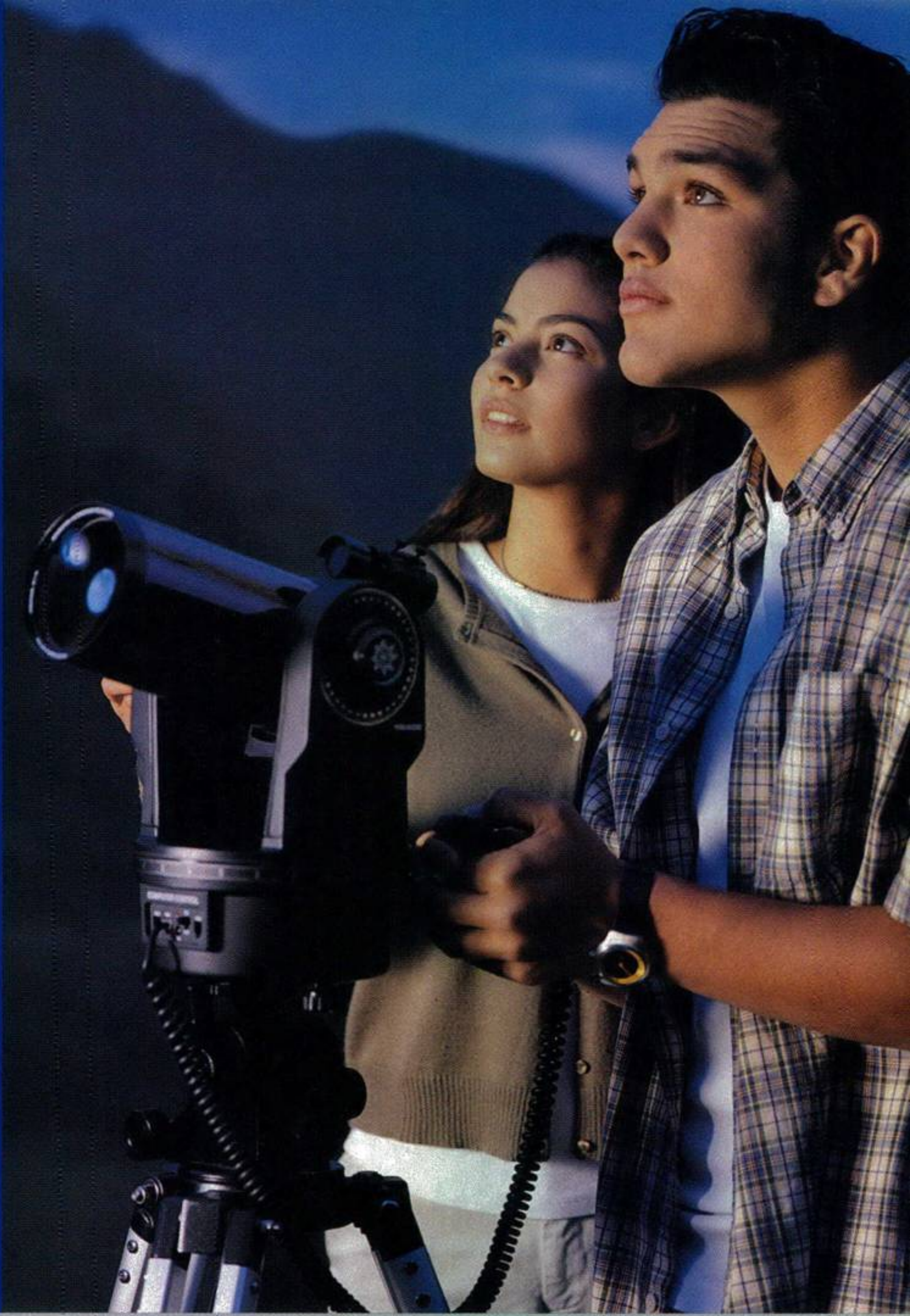

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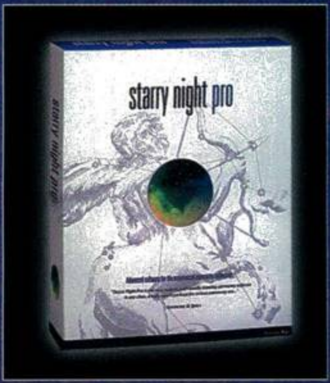

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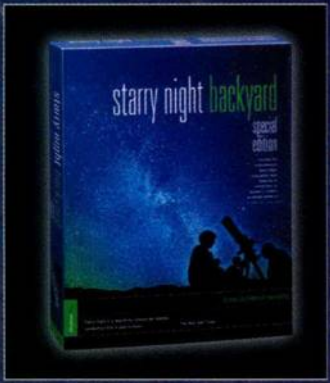

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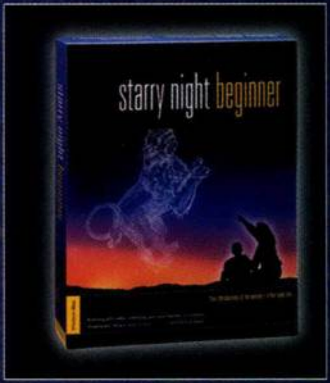

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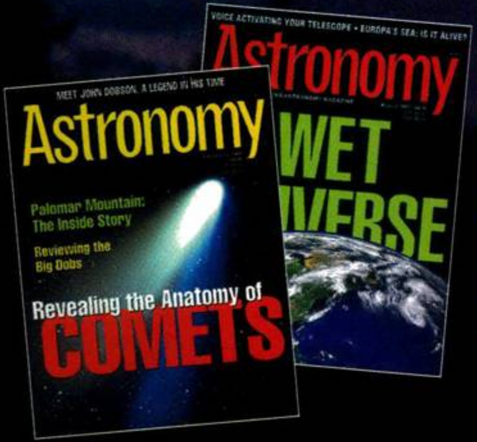
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**"I see dead people,"** whispers the terrified kid in the 1999 hit movie *The Sixth Sense*. Cole Sear, the film's central character, is an eight-year-old boy who can see the invisible spirits of the dead. In the movie's universe, ghosts exist alongside of us but can't interact with the living. Despite the melodramatic, paranormal story line, the film raises a deep and abiding question in the realm of physics: How much of the universe do we live in? How much of it are we part of?

You wake up, take a shower, and drive to work, always believing that the world you experience is the world that is. Could there be more? Could there be a universe alongside this one, a parallel world that moves right through you? As physicists and astronomers have pushed inward to the heart of matter and backward to the moment of creation, they have been thrown against this question. Their answers make it clear we are already missing a lot of the universe, with even more potentially unseen right under our noses.

Welcome to the invisible worlds of dark matter and the shadow universe. Physicists who study matter on its most fundamental level have already found the seeds of a parallel universe. To understand it, you have to go back to the beginning, all the way back. Less than a billion billion billionth of a second after the Big Bang, the universe was a roiling cauldron of energy. It was a nasty place, but in a sense, it was also a simple place. Conditions were so extreme that none of the forms of matter we are familiar with today could exist. Our world had yet to be born.

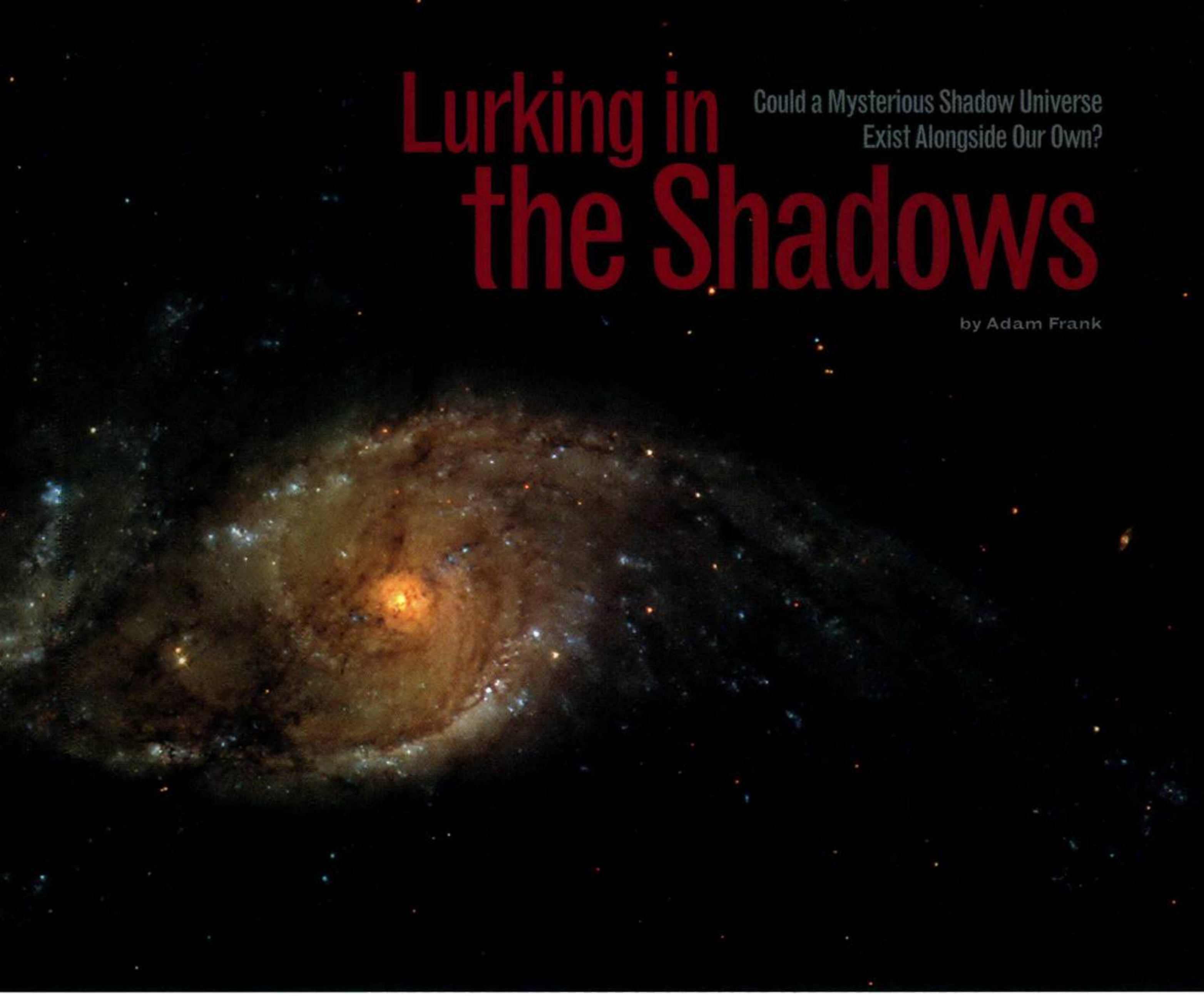
We know very little of what this fetal universe was like. We do know that as it expanded, the universe cooled and the forces and particles we recognize today froze out of the hyper-hot primordial stew the way ice crystals freeze out of liquid water. From formlessness, form coalesced. You might call this the "big freeze." The stuff we are built of, the stuff which went on to become stars and galaxies and planets, emerged at this specific moment in cosmic history. In the big freeze, the original simplicity of the early universe was broken, creating the potential for the rich structure of which we are so happy to be part. Our world, however, may not have been the only one created.

Good theoretical physicists never let a little thing like ignorance stand in their way. Despite the beyond-the-pale extremes of the early universe, they have sketched out how

# Lurking in the Shadows

## Could a Mysterious Shadow Universe Exist Alongside Our Own?

by Adam Frank



**Dark matter, perhaps in its shadow form, controls the cosmic dance of NGC 2207 (left) and IC 2163.** NASA and the Hubble Heritage Team (STScI/AURA)

the story of the universe's birth might be told. There is one version of the story which includes a shadow world.

Two distinct families of matter are created in the big freeze. One kind of "stuff" constitutes the world we know, the protons and electrons and other denizens of the subatomic world that have combined into splendid forms like us. The other family of matter would represent the shadow world. It would exist alongside of, but separate from, our own world.

### Into the shadow universe

The two universes of normal and shadow matter could inter-penetrate but not interact. In time, a rich shadow universe would evolve along with our own. Shadow planets could form around shadow stars and be populated by intelligent shadow beings. Stranger still, since the two worlds wouldn't interact, shadow matter could exist alongside normal matter right here on Earth. How could two universes exist in the same place? To attack this question you first have to ask how the universe you live in exists at all.

Musing over the nature of reality can seem a pretty sterile affair. When some philosopher wannabe starts pondering the existence of a chair in front of us, there's a strong urge to take a cue from the World Wrestling Federation and hit him or her over the head with it. "There," you want to say. "Now how real do you think it is?"

In physics and astronomy, things are different. You can't take any answers for granted. For example, the chair that downed the philosopher is really 99 percent empty space. The atomic nuclei in the chair, where essentially all the mass resides, are as far apart from each other as stars are in a galaxy. So why, when you sit down, don't the atoms in your butt just sail right past the atoms in the chair? The answer gets you halfway to the shadow world. The atoms in the chair exert forces that reach across space and affect the atoms in your butt. On the most fundamental level of fundamental physics, forces count for everything and matter is secondary.

Without some kind of push or pull — in other words, a force — atoms would not know that their companions exist. Without an exchange of forces, even a head-on collision

**Some theorists think that shadow matter may play a key role in forming spiral galaxies, such as the Sombrero (M104).** European Southern Observatory

between two particles would produce no effect. Like a ghost walking untouched through a wall, the two particles would pass right through each other.

The universe we live in has just four ways to push or pull: gravity, electromagnetism, the strong nuclear force, and the weak nuclear force. These are the only forces that emerged from the big freeze. We all have direct experience with the first two forces. Gravity is what keeps your feet on the ground. Electromagnetism is the explicit reason why your butt doesn't slip through the chair (electromagnetic forces between chair atoms and butt atoms give both their appearance of solidity). The strong and weak nuclear forces are not so familiar because they operate only on subatomic scales. They are responsible for giving us the elements, allowing gold its luster and sulfur its stench.

The four forces bind the world together in its diversity of shape, structure, color, and form. However, things could have been different; there is nothing mystical about the number four. Like so much in life, the number and form of the forces that emerge from the big freeze has an element of randomness to it, and that's what makes the shadow world possible.

## Matter without feeling

Have you ever known unrequited love? If so, you already understand a deep principle of subatomic physics. You are attracted to someone, but that person doesn't know you exist. In the same way, some forms of matter don't "feel" all four forces. A neutron, for example, has no electric charge so it doesn't care about electromagnetism. Create a new form of matter that doesn't feel any of the four forces and it wouldn't feel our world at all. It would exist but be undetectable. If this exotic stuff had its own set of forces then it could bind together in interesting forms and create a rich universe parallel to our own. Each universe would pass through the other without ever knowing of the other's existence.

In the mid 1980s, some physicists recognized the shadow world in equations describing the universe during the big freeze. The math hinted that as the universe cooled, all the normal forces and particles would get a shadow twin. Only

**Ninety percent of the material in a galaxy cluster, such as Abell 1060 in Hydra, seen here, consists of dark matter.** © Anglo-Australian Observatory

gravity would be shared between the two worlds. Shadow electrons, for example, would feel only shadow electromagnetism and would be "neutral" to our world's version of that force. By having a full complement of forces available to it, the shadow world could evolve into as varied a place as the one we inhabit.

## Giving form to shadows

For now, unfortunately, the shadow world is only the stuff that dreams are made of. Shadow matter remains a theoretical curiosity, a shadow of a possibility existing only on paper. But researchers are not giving up on the existence of a real parallel universe. In fact, they already know exactly where to find one. While shadow matter is simply an idea, dark matter is an inescapable fact.

Astronomers already know that most of the universe exists in a dark, invisible form. For more than 20 years, evidence has gathered steadily that well over 90 percent of all the stuff in the cosmos reveals itself entirely through the push and pull of a single force — gravity. Galaxies spin faster than can be accounted for by the pull of their own visible mass. Galaxies in clusters swarm around a common center at speeds too high to be gravitationally driven by the luminous matter we can see. In these and countless other cases, astronomers have been forced to admit that something else is out there. The dark matter continuously provides the gravitational tugs that keep what we can see in motion. As the third millennium opens, there can be little doubt that dark matter exists.

It is also clear that whatever dark matter is, we aren't part of it. At first astronomers believed dark matter was normal stuff like us, subject to all four universal forces. Dark matter was then just material not emitting much light, things like rocks or dead stars. As the sophistication of their instruments and theories progressed, astronomers have been forced to abandon that hope. Dark matter is "exotic" in a similar way to shadow matter. It does not respond to the full complement of forces born in the big freeze. It is not stuff like us. As you read this page, countless dark matter particles

**The largest concentration of dark — and possibly shadow — matter in the local universe belongs to the Great Attractor.** European Southern Observatory

are streaming untouched through your body like sunlight streaming through a window.

Yet there is a big difference between dark matter and shadow matter. The dark stuff doesn't appear to have its own special forces to bind it together. All it can feel is gravity and perhaps the weak nuclear force. The weak force is, well, weak, and so for that matter is gravity. You need to gather a lot of stuff together before gravity becomes useful. You can not, for instance, hold a person-sized lump of matter together with just gravity. With only these two forces at its disposal, no lumps, or at *least* no interesting lumps like trees or people, can form in the dark universe. Even making a star or planet is difficult with just gravity alone — the electromagnetic force is crucial to slowing material down enough to hold it in one place. The dark matter universe can hold no dark stars or dark planets populated by dark matter aliens.

So, does a parallel universe exist? The answer is yes — but we are it. With more than 90 percent of the cosmos composed of an invisible form of stuff that barely notices our world's presence, it seems that we are the outsiders. All the luminous stars and galaxies stretching across space and time, all of our kind of stuff, is no more than tiny bubbles of foam riding on a vast dark matter sea. In a very real sense, we do not even live in the universe that is. We are an afterthought.

## Diamonds in the rough

That may seem like the ultimate cosmic insult, the grandest statement yet of our insignificance. But just the opposite is true. After all, a diamond's worth lies in the fact that it is not dirt. It is uncommon. In all the dark matter world there can never be anything as wondrous as a star, a meteor, or even a blade of grass. Our share of the universe may be small, but it is, by far, the only one worth the time. 🅰

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*University of Rochester astrophysicist Adam Frank is a member of* Astronomy's *Editorial Advisory Board. His previous article was "Probing the Birth of Starlight," in the September 2001 issue.*

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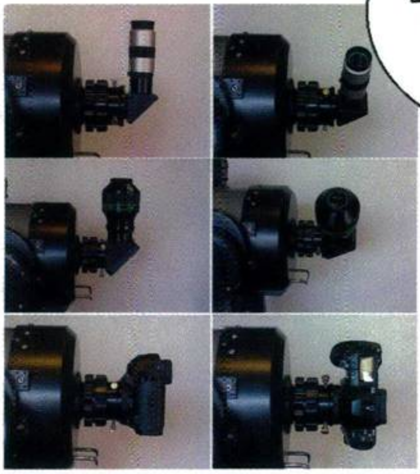

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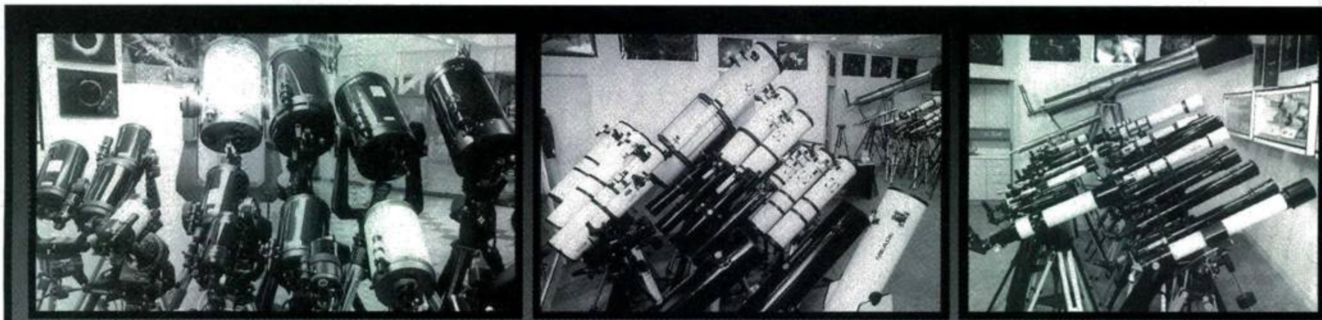

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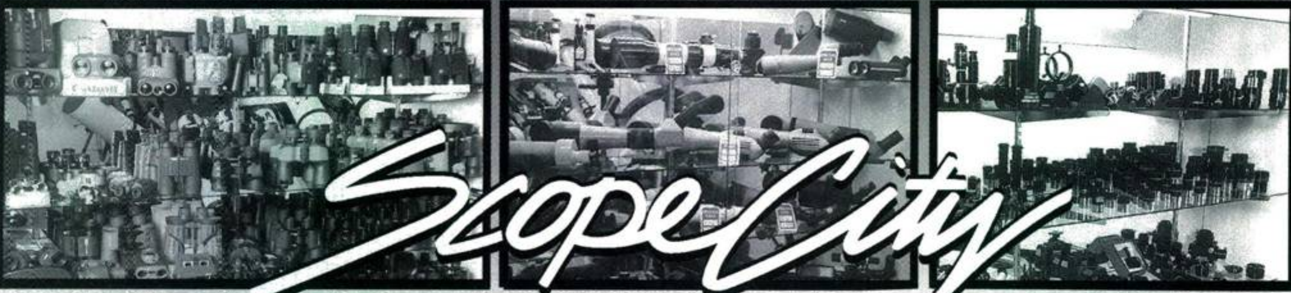

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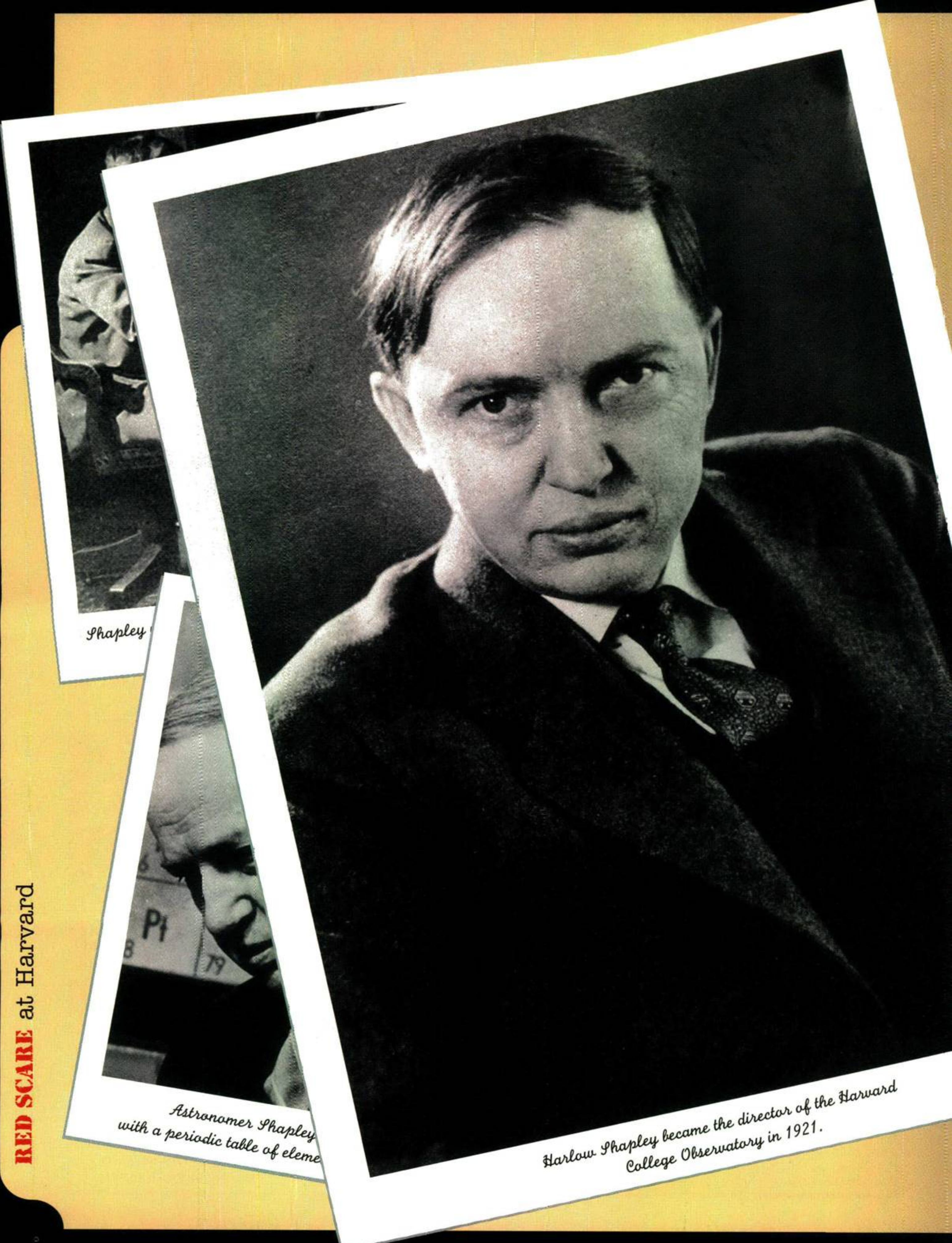


Shapley

Astronomer Shapley
with a periodic table of eleme

Harlow Shapley became the director of the Harvard College Observatory in 1921.

# RED SCARE at Harvard

### Harlow Shapley's thick FBI file suggests he was more than an accomplished astronomer; he was a dangerous character.

by Tony Ortega

Harvard College Observatory

It was the spring of 1947, and the Federal Bureau of Investigation was hot on the trail of a suspected Communist. On March 28, Federal agents in Los Angeles sent word to Washington that the supposed Soviet sympathizer had sent a letter to a prominent scientist.

The suspicious letter was addressed to Edwin Hubble. It had been sent by Harlow Shapley.

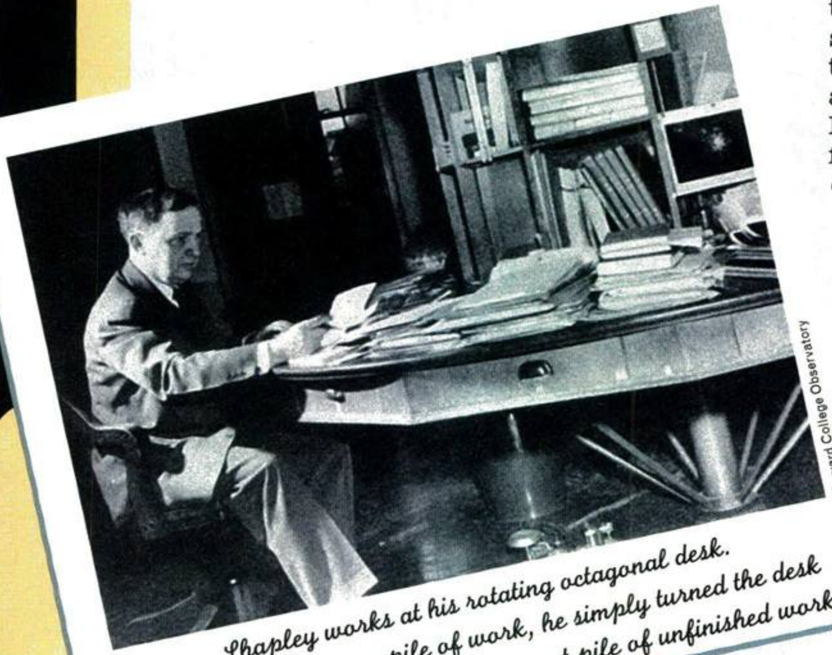
Two of America's greatest astronomers, these men are largely responsible for our current understanding of the structure of the universe and the solar system's place in it. But to the FBI, Shapley was a dangerous character.

Records show that for two months in 1947, FBI agents recorded the addresses of every piece of mail that Shapley sent or received. One of those letters went to his old Mt. Wilson colleague, Hubble.

This extraordinary surveillance was just part of the seven years of government spying on Shapley that ended in 1953, a year after he retired as Harvard College Observatory's director. Copies of Shapley's 461-page FBI dossier continued to be shared with various federal agencies well into the 1960s. (Shapley died in 1972.) At the height of the FBI's monitoring, however, when agents were aware of even minute details of his life, Shapley told a friend that he doubted the agency was following him.

That's in the massive file, too.

*Astronomy* obtained Shapley's FBI file with a Freedom of Information Act request. The dossier shows that FBI agents relied on informants at Harvard, moles in the astronomical community, and infiltrators in national political organizations to watch Shapley closely. The FBI even spied on the 1946 convention of the American Association of Variable Star Observers, which Shapley attended. (FBI agents were concerned that Shapley was trying to recruit the AAVSO members to turn their mild-mannered pursuit of measuring star brightnesses to something more nefarious. What this activity might have been is not clearly spelled out in the file.) But after seven years of eavesdropping, the FBI could not establish that Shapley was – or had ever been – a member of the Communist Party.



*Shapley works at his rotating octagonal desk. When he finished one pile of work, he simply turned the desk to the next section and dug into the next pile of unfinished work.*

Harvard College Observatory

What does emerge from the file is a complex portrait of an astronomer who didn't like what his government was doing with nuclear arms, a fiercely independent and passionate man who used his position as one of the most visible of American scientists to battle the pogroms of the red-baiting House Un-American Activities Committee and Senator Joseph P. McCarthy. What appeared suspicious to post-war FBI agents — Shapley's concern for war refugees and for the welfare of foreign scientists, as well as Shapley's vocal opposition to lynchings of blacks in the South — seem like ringing endorsements today. But not everything in the file is flattering by today's standards. According to the FBI, Shapley could at times be insensitive and petty. Overall, the picture of Shapley that takes shape among the blacked-out sections of the file the FBI still won't release is that of a man who irked government officials in a time when conformity was considered a patriotic virtue.

In a typical assessment, the file reads: "Confidential Informant [redacted] offered the following estimate of Shapley, based upon his association with him: 'He is a stubborn advocate of his own ideas and one of the supreme egotists of our time. He has an inherent dislike for authority, and will invariably do the opposite to what he is told or supposed to do.'"

Shapley would probably not have quibbled with that appraisal. Appointed director of the Harvard College Observatory at only 35 years of age, he was not short on self-confidence.

Shapley had made his reputation with one of the most monumental discoveries in astronomy since Copernicus's displacement of Earth from the center of the universe. Four hundred years after Copernicus made Earth circle the sun, Harlow Shapley moved humanity even farther from the center of creation. Using observations of Cepheid variable stars in globular clusters that he made at Mt. Wilson from 1914 to 1921, Shapley radically revised the scale of the universe, finding that the Milky Way Galaxy was about ten times bigger than previously thought. Even more surprising, he discovered that the solar system was not at the Milky Way's center but out near its periphery. He estimated, after a few revisions, that the sun and its planets were some 30,000 light-years from the galaxy's true center, which he correctly located in the direction of Sagittarius.

Before he became a world-famous astronomer, however, Shapley started out as a journalist and even, he later admitted, did some spying of his own.

In his autobiography, *Through Rugged Ways to the Stars*, Shapley relates the time he sat outside the office of a political candidate in tiny Chanute, Kansas. He'd been kicked out by the candidate, who didn't like the newspaper where Shapley worked, but the young political reporter realized he could hear just fine outside, and took down everything he heard in shorthand.

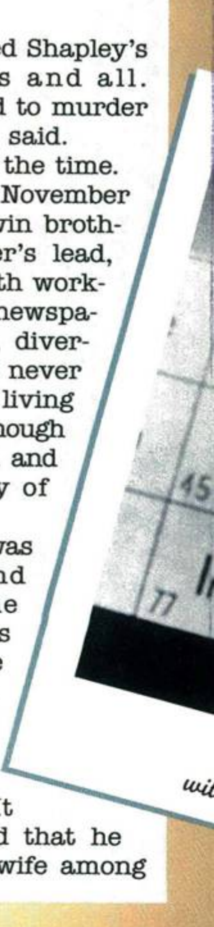
## THE NEWSPAPER DIVERSION

The next day, the *Daily Sun* printed Shapley's notes verbatim – coarse words and all. "Consequently [the politician] wanted to murder me and blow up everybody," Shapley said.

He was all of sixteen years old at the time.

The Missouri native was born on November 1, 1885, the son of a farmer. His twin brother, Horace, would follow their father's lead, but Shapley wanted nothing to do with working the land. He found working in newspapers a more exciting, if low-paying, diversion, but soon realized that he would never become an editor and make a decent living without a degree. In 1907 he raised enough cash to pay for a year of high school and then packed off for the University of Missouri at Columbia.

The university's journalism school was still a year from opening up, and Shapley had no real idea what he wanted to study in the meantime. His first term, in fact, he opened up the university's catalog and decided to take the first class listed. When he realized he didn't know how to pronounce "archaeology," he skipped to the next listing, "astronomy." It must have been fate. Shapley found that he enjoyed the subject, met his future wife among



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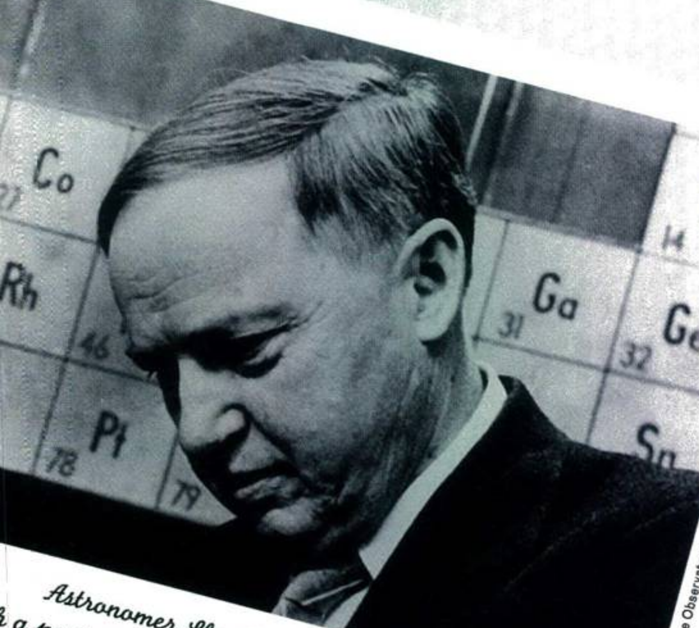
his astronomy colleagues, and earned a bachelor's and master's degree in only four years.

He then won a fellowship to study with Henry Norris Russell, the country's foremost astronomer, at Princeton. Under Russell, Shapley made his reputation for solving the orbits of binary star systems through the use of complex equations. That landed him a research job at Mt. Wilson, which began in 1914.

Using the 60- and 100-inch telescopes at the observatory north of Los Angeles, Shapley made his great discovery about the Milky Way Galaxy's true size and the solar system's place in it. But other scientists were skeptical about Shapley's findings, including a scientist named Heber Curtis at Lick Observatory outside San Jose. George Ellery Hale, Mt. Wilson's wealthy patron, convinced Shapley to come to Washington, D.C. in 1920 and promote his ideas by facing off with Curtis in a friendly airing.

The event would later come to be called the Great Debate, although Shapley felt it was somewhat blown out of proportion. He had come ready to convince his listeners that the Milky Way was much larger than previously thought and that the solar system was far from its center. But Curtis, after casting doubt on Shapley's data, argued something different – that the "spiral nebulae" were actually galaxies outside the Milky Way. Shapley, relying on erroneous data which suggested the spiral nebulae were nearby, said that Curtis was wrong. Both were partly correct: the Milky Way was extremely large, the solar system was on its periphery, and the spiral nebulae were external galaxies.



Harvard College Observatory

*Astronomer Shapley often lectured*
*h a periodic table of elements as his backdrop.*

The notoriety of the event helped Shapley land Harvard Observatory director's job a year later, in 1921. For the next 31 years he greatly expanded research at the institution, making it more of a teaching establishment.

Harvard College Observatory

*Shapley lays the cornerstone for Harvard's new observatory.*

## AT THE PERIPHERY OF POLITICS

As director of Harvard's observatory, Shapley also found himself on the periphery of national politics, and he took advantage of it. An outspoken liberal, Shapley actively helped European scientists escape the fascist regimes of Spain and Germany in the 1930s and 1940s to find work in North America.

In the postwar anti-radical hysteria that gripped the United States, Shapley's political activities made him just one of many intellectuals, artists, and journalists FBI director J. Edgar Hoover investigated for Communist ties.

It's already well known that Shapley ran afoul of the anticommunists in Congress. In 1946, House Un-American Activities Committee member John E. Rankin subpoenaed Shapley to question him about campaign contributions made by a liberal organization he chaired.

What Shapley didn't know, however, was that by the time he received that subpoena in November, the FBI had already been under surveillance for more than five months. Stamped "SECRET," Shapley's hefty dossier was only declassified in 1998. In a calm, official tone, the FBI file describes Shapley's past and his connections to various political and professional organizations. In a section about the Rankin subpoena, the report discusses private conversations and confidential attorney-client conferences that Shapley engaged in as he prepared to appear before the congressional committee. Although no mention of electronic surveillence is made anywhere in the lengthy file, such descriptions of private conversations suggest that Shapley's phone was tapped.

To an associate, for example, Shapley admitted that he possessed the political connections to quash Rankin's subpoena, but he chose to face the southern Democrat in a showdown he hoped would lead to the end of HUAC itself.

The episode did generate a great deal of publicity. After their tempestuous closed-door session on November 15, Rankin and Shapley emerged into an eruption of flashbulbs. "I have never seen a witness treat a committee with more contempt," Rankin said. Shapley, meanwhile, accused Rankin and HUAC of "Gestapo methods."

Shapley's behavior in the closed meeting quickly became lore among those people who objected to HUAC and its tactics. According to Shapley's account of the hearing, which he told the next day to his Harvard colleague Bart J. Bok and others, Rankin had objected to Shapley's showing up at the hearing with an attorney. Somehow, Shapley said, Rankin managed to maneuver his lawyer out of the room. Rankin then noticed that Shapley had brought along a secretary who was taking notes. Rankin kicked her out and told Shapley that the committee would provide him with its own record of the hearing. But Shapley said Rankin really exploded when the scientist began taking down the proceedings in shorthand. Angered that Shapley continued to defy him, Rankin approached the witness and tore away his shorthand notes, and the hearing abruptly ended.

*Harvard College Observatory staff members, including a young director Shapley, fourth from left in the sec*

But the FBI file suggests that there was more to the hearing, and that Rankin was angry for reasons other than Shapley's ability to take down notes quickly. Soon after the incident, Shapley telephoned a friend to give an account, telling her to remember that "even the walls have ears." That conversation is detailed in the FBI file. Shapley told his friend that he and Rankin had argued over Shapley's efforts to bring scientists to America with the help of the Joint Anti-Fascist Refugee Committee. Rankin said that the JAFRC was a Communist organization; Shapley denied it.

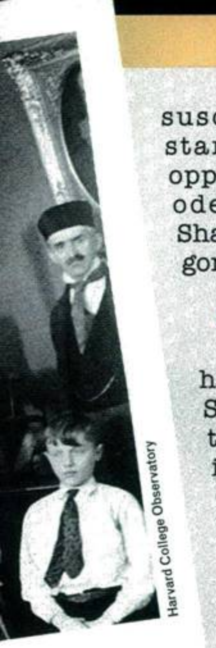
After some arguing, Rankin then turned to a letter Shapley had written to a Massachussetts congressional candidate, Martha Sharp. At the time, Shapley was chairman of a left-leaning state political organization, the Independent Citizens Committee of the Arts, Sciences, and Professions, which had given funds to Sharp's campaign. For political reasons, Sharp had not made public her acceptance of the money.

Shapley said he would only answer questions about his letter if Rankin admitted a congressional operative had burglarized Sharp's office in an attempt to smear her.

At that point, Shapley said, Rankin threatened him with contempt. Those threats were repeated, he said, when Rankin realized that Shapley hadn't brought ICCASP documents that he'd been ordered to produce. (The contempt charges were eventually dropped.)

Shapley returned to Harvard to find that he'd become a hero to its students. His defiance of HUAC thrust Shapley into even more prominence nationally, a development he later decided was a mixed blessing. As a result of the battle with Rankin, Shapley was frequently asked to speak at colleges about HUAC, U.S. foreign policy, and Soviet relations. The FBI, meanwhile, continued to watch Shapley's movements.

In 1945, for example, Shapley had been one of the scientists who took advantage of the end of the war to travel to Moscow to celebrate the 220th anniversary of the Russian Academy of Sciences. A Yale professor told the FBI that Shapley had handled the invitations for the American scientists, and an FBI informant who was present gave agents a description of the event. "[Redacted] relates that the visiting scientists were accorded one of three types of treatment by their Soviet brethren. Those who indulged in alcoholic beverages were quickly intoxicated and remained in that state throughout their stay in Moscow. Those more readily susceptible to the charms of the opposite sex found their every desire gratified, and those who were of a higher moral caliber, in the informant's opinion, but who were


Harvard College Observatory

d row.

susceptible to flattery were so constantly eulogized that they had little opportunity to do other than hear the odes written in their honor . . . . Shapley was constantly in either category one or three."

## COMMUNIST SYMPATHIZER

Repeatedly, Shapley is accused of harboring sympathies that paralleled Soviet interests. A 1947 report claimed that Shapley promoted a "political line in no wise different from that of the Communist Party, U.S.A." As an example, however, the unnamed report writer cited Shapley's lobbying efforts to convince Congress to establish the National Science Foundation. (The NSF today underwrites more than $3 billion of the country's scientific research. But in 1947, the effort to give government funds to scientists seemed radical to worried FBI agents.) The FBI also took an interest in Shapley's openness about his atheism. Calling him a "worshipper in the temple of Science," an agent noted that Shapley worked on Christmas Day, 1946, as a gesture of his nonbelief. But the report acknowledges that Shapley showed respect for the faith of other people: "He has never attempted, to the knowledge of these informants, to willfully interfere with the beliefs and traditions of others."

Less flattering is the file's claim that on a few occasions the professor abused people in less powerful positions. In 1947, according to the file, one of Shapley's students, who was funded by the G.I. bill, had angered him by ridiculing his political activism. Shapley put pressure on a residential headmaster who owed him his job to punish the student. In another episode, the file claims, Shapley refused to pay Radcliffe students minimum wage for mathematical drudge work at the observatory. The young women resigned in protest, and Shapley is claimed to have said he would rather get along without them than pay 75 cents an hour.

By 1948, the FBI seemed convinced that no concrete connection between Shapley and Communism would turn up. "There is . . . no information or evidence indicating that Harlow Shapley is now or ever has been a member of any Communist Party," reads a report dated March 27. Several times, the FBI refers to a Boston informant who claimed that Shapley was a "concealed" member of the Communist Party, but this does not seem to convince the agency of a real tie. Shapley is repeatedly criticized for harboring pro-Communist views and for speaking negatively about U.S. foreign policy, but overall he's described merely as a headstrong individualist: "[Redacted] volunteered further his personal opinion that Shapley was much too independent in nature to be a member of any Communist Party."

After March 1948, Shapley began to curtail his political activity, telling people that the Harvard president, James B. Conant, was hearing too many complaints about him. By 1949, according to the report, Shapley had promised the school's administration that he would avoid bad publicity. Shapley's lower profile, however, didn't keep Senator Joseph P. McCarthy from attacking him the next year. During a committee meeting in March, 1950, the Wisconsin senator accused Shapley of belonging to 36 Communist-front organizations and of being an unsavory character. Shapley called McCarthy's charges "hysterical nonsense" and said "I have only to say that the senator succeeded in telling six lies in four sentences . . . probably the indoor record for mendacity."

Later that year, a Senate subcommittee cleared Shapley of all of McCarthy's allegations. In 1952, Shapley reached Harvard's mandatory retirement age of 66 and stepped down from his post at the observatory. He had overseen massive projects produced by 25 large telescopes around the world, including the *Shapley-Ames Catalog of External Galaxies*.

Harvard College Observatory

*Albert Einstein and Shapley shared similar public honors.*

After his retirement, he continued to work at the observatory and teach classes. And the FBI continued to keep an eye on him. Apparently, however, they assigned a less knowledgeable agent to keep an eye on the aging scientist. In a 1953 report, an entry in Shapley's file reads: "Informant [redacted] stated on [redacted] that although Subject is the retired director of the Harvard Observatory . . . he continues to be an active professor of astrology."

Someone has crossed out the word and written in "astronomy." ■

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*Tony Ortega lives in Santa Monica, California, where he works as a writer for* New Times, *Los Angeles.*

# *Caught in the Tarantula's web*

## New studies finally reveal the source of the Tarantula Nebula's best-kept secrets.

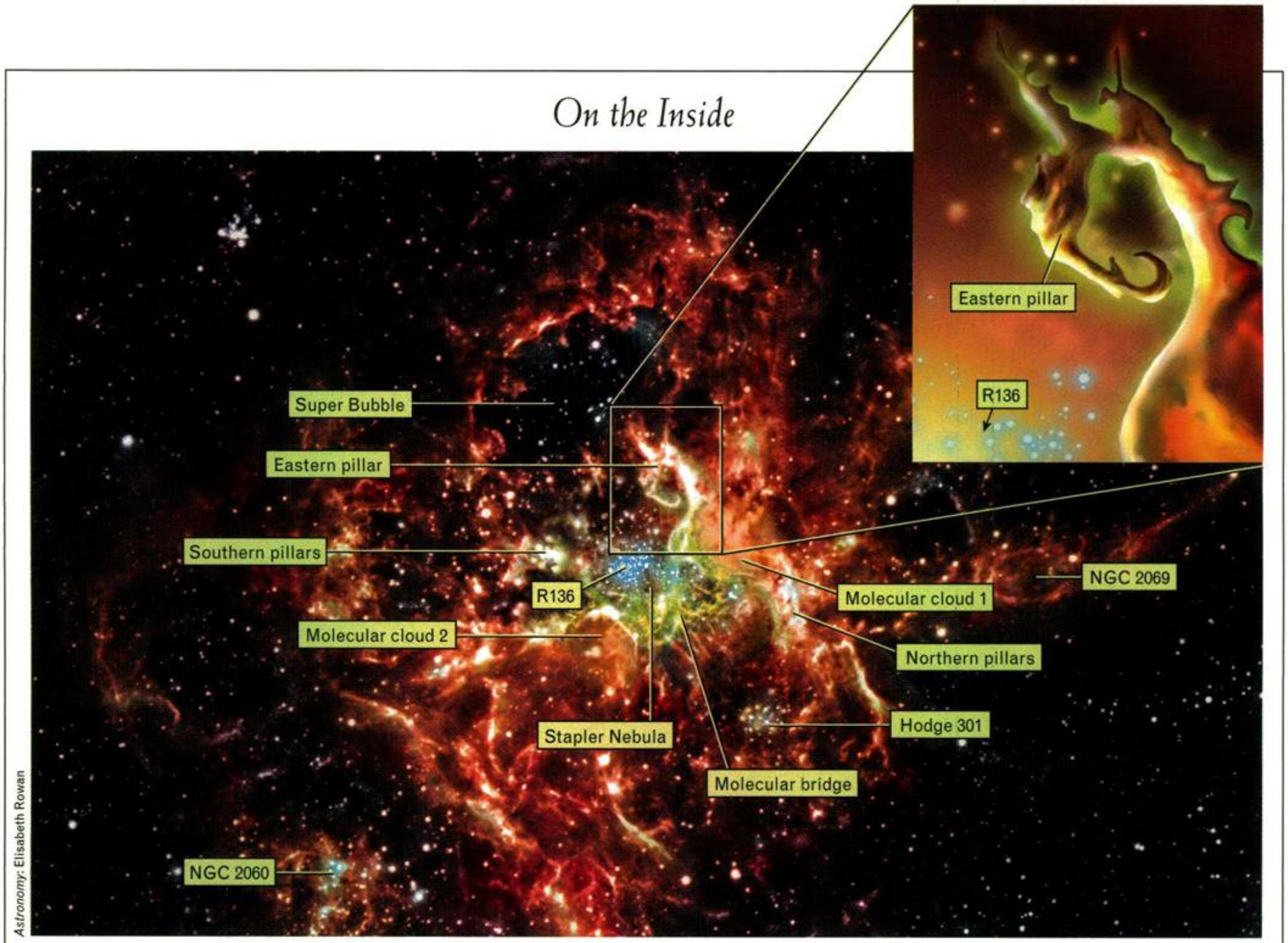
**by Greg Clark**

Star-swollen legs outstretched, the Tarantula Nebula lies in its Magellanic lair like a bright spider eagerly cradling two succulent, but shrouded, clouds of prey.

From our galactic vantage point, peering 170,000 light-years due south through the constellation Dorado, the Tarantula Nebula, also known as NGC 2070, the Looped Nebula, and 30 Doradus, is clearly visible to the unaided eyes of southern-sky observers as it outshines its stellar and nebular compatriots in the Large Magellanic Cloud (LMC). With every step of magnification, however, this giant emission nebula, fueled by an ultraviolet deluge from one of the most massive and brightest star clusters known, enchants more and more, as it slowly reveals a roiling cauldron of immense and continuous star formation.

**Hot from the furnace: The Tarantula Nebula (NGC 2070) dangles from the northeast side of the Large Magellanic Cloud like a newly blown piece of abstract art glass strung out to anneal.** Luke Dodd

## *On the Inside*



*Astronomy*: Elisabeth Rowan

**An observer dropped into the powerhouse Tarantula Nebula would face a most hostile panorama of bizarre sights. Away from the nebula's center, the sheets of luminescent ionized hydrogen would shimmer like the northern lights in overdrive, but near the central cluster, the power of the stars would likely overwhelm such sights with their own blasting bright light and blistering radiation. Each of the stars in R136 can be up to one million times brighter than the sun. It's safe to say darkness would be a long-forgotten commodity.**

Like a set of nested Russian Matrioshka dolls, the Tarantula Nebula has saved its secrets for those with the patience, wisdom, and technology to reveal them. Now, thanks to the current generation of space-based observatories like the Hubble Space Telescope (HST), the Chandra X-ray Observatory, and the European Space Agency XMM-Newton X-ray Observatory at their disposal, astronomers are just beginning to understand the significance of the Tarantula, its features, and the place that it holds in the understanding of the universe at large.

### A Rosetta of Sorts

Among astronomers, the Tarantula is recognized for being just as important to the understanding of giant starburst HII regions (see "Nature's Red-Light Districts," page 53) as the Rosetta Stone was to 19th-century archeologists, who, until its unearthing, could make only blind guesses about the meaning of ancient Egyptian hieroglyphic inscriptions.

Ionized hydrogen regions — known to astronomers as HII regions, after the chemical notation for ionized hydrogen — are shining stretches of gas and dust lit up by the effects of intense ultraviolet radiation from nearby young stars. The Milky Way Galaxy is home to dozens of these luminous spectacles, which have become favorite targets among amateurs and professionals alike: the Omega Nebula (M17), the Eagle Nebula (M16), the Trifid Nebula (M20), the Orion Nebula (M42), the Lagoon Nebula (M8), and many others.

Though somewhat familiar, the LMC's Tarantula Nebula is also quite different from notable galactic HII

NASA/J. Trauger (JPL)/ J. Westphal (Caltech)

**At the heart of the Tarantula, fresh stars are continually forming at the head of massive dust pillars and deep inside clouds of molecular gas.**

regions. First of all, it absolutely dwarfs them. If the Tarantula were to occupy the present location of the Orion Nebula (roughly 1,500 light-years from Earth), it would be larger than the entire constellation of Orion and would span more than 22° in the sky — the apparent width of 44 full moons. It would shine as brightly as the Milky Way, with its immense ionizing central cluster (R136) as a bright glaring beacon at its center (see "Dorado's Infamous Star(s)," page 52).

Yet, compared to large HII regions in other galaxies, the Tarantula Nebula is still only a puny spark. Starburst galaxies such as M82 are chock full of scores of larger starburst regions, all firing simultaneously.

## Stepping Stones

What sparks such coherent, efficient star formation at various points in time and space is a mystery that many astronomers are eager to investigate. But they have been thwarted so far by their inability to resolve individual stars or to divine the detailed physical processes responsible for large starburst regions far away.

The good news is that the key to the dilemma may lie with the Tarantula. As the largest and brightest HII region in the local neighborhood of galaxies, the nebula is perfectly placed to help astronomers answer the difficult puzzles of larger HII regions and starburst galaxies. In both size and distance from Earth, the Tarantula Nebula lies right between small, nearby, and well-studied HII regions and the mysterious giant HII regions in faraway galaxies.

"[The Tarantula] is the essential stepping stone," says Jeff Hester, an astronomer at Arizona State University who has studied many HII regions including the Trifid, Eagle, and Tarantula. "It's a rung in the ladder that lets you go from understanding HII regions very nearby to understanding the objects that you see much further away in other galaxies. And if we didn't have [the Tarantula] then the step would be too big. You could never confidently go from one rung of the ladder — stepping over where [the Tarantula] is — to the next rung of the ladder."

Alex de Koter, an astronomer at the University of Amsterdam, has studied the distribution of stars in the Tarantula's central cluster with the hope of learning more about large-scale star formation. "These starburst galaxies

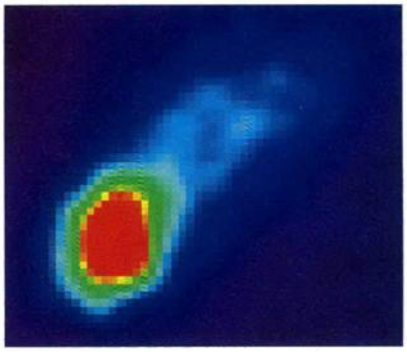
## *The Tarantula's Magellanic Menagerie*

Many extraordinary and interesting objects conspire to make the Tarantula Nebula one of the richest locations for astronomers to study. The three examples below constitute a mere fraction of the Tarantula's complexity.

Hubble Heritage Team(AURA/STScI/NASA)

### Hodge 301

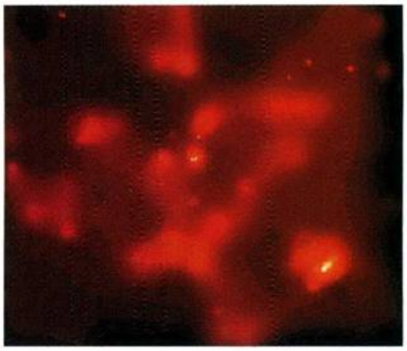
It's clear, from the presence of immense regions of evacuated interstellar material, that the Tarantula Nebula has been rocked by multiple supernovae blasts. One of the largest perpetrators of this astronomical ordnance activity, a star cluster called Hodge 301, can be found at the northern edge of the nebula. The stars of Hodge 301 are thought to be about 10 times older than those in the Tarantula's central cluster R136. As a result, many of Hodge 301's stars have had the requisite time to evolve and reach the supernova stage, sculpting out the surrounding material as they spew their contents across the nebula. At present, three red supergiant stars reside in Hodge 301 that will undoubtedly explode in the next few million years.



NASA/Chandra/Townsley/PSU

### N157B

N157B appears completely ordinary in optical observations. Nonetheless, this strange x-ray supernova remnant is everything but ordinary. Deep in the center of a magnetic-field-induced synchrotron radiation pocket, N157B proudly displays its strong central pulsar source and, more interestingly, an energetic tail-like wake, stretching more than 15 light-years behind. This tail seems to resemble that of a comet, hence leading to the pulsar's formal designation as a cometary pulsar. Its discoverer, Daniel Wang, an astrophysicist at the University of Massachusetts at Amherst, believes the tail is most likely the result of the pulsar's supersonic motion through the Tarantula Nebula's interstellar material. Moreover, the pulsar probably received its boost from the supernova explosion that created the N157B remnant.



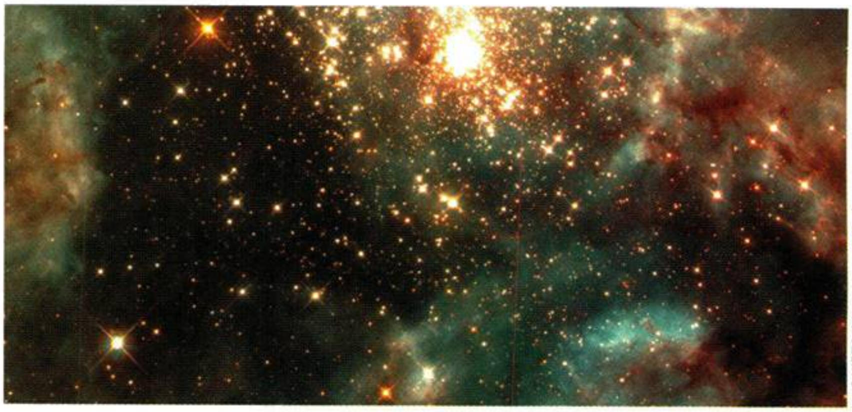
NASA/Chandra/Townsley/PSU

### X-Ray Winds

The heart of the nebula is filled with intense x-ray sources that are not yet fully understood. Penn State's Leisa Townsley is working on interpreting the x-ray observations from the Chandra X-ray Observatory. She is comparing these with optical images of R136 to determine where the high-energy emissions are coming from and whether they are related to stars that are seen in optical light. The likely explanation for many of these sources, according to Townsley, is colliding stellar winds in massive binary star systems. Several of the massive stars in R136 are binaries consisting of two massive, gravitationally bound stars. When the high-pressure, charged-particle winds from these stars slam together, the shock of the violent collision produces x-rays, shock-heated by the collective effect of many supernovae exploding over time.

are so incredibly luminous, you can see them throughout the universe. And because you can see them at every distance, you see them at every time, which means that they can be used as probes for the star-formation history of the universe," says de Koter. As such, they're a perfect tool for answering important questions like: In what epoch did the universe produce the most stars?

## Dorado's Infamous Star(s)



NASA/STScI/N. Walborn/R. Barba

**Hubble's infrared eye peers deep into R136.**

So dense, young, and powerful is the Tarantula Nebula's central star cluster, R136, that when it was first observed closely, astronomers could hardly believe what they were seeing.

The names originally given to the region by early astronomers (both R136 and 30 Doradus) suggest that they thought it to be a single star or starlike object. In fact, as little as 20 years ago several working groups concluded that the dubious uberstar might even possess 2,000 to 3,000 times the mass of the sun. Despite the fact that astronomers now know this belief to be erroneous, the old monikers continue to stick.

It's true that the idea of such a giant star seems extreme in hindsight (as it did to many at the time). At that time, however, the alternative explanation seemed even more radical — that the heart of the nebula held more than 30 of the rarest of all known star types, the blistering, infant O3 star.

It seemed remote at best that the Tarantula Nebula could hold in one place a complex of three dozen stars that were considered rare freaks of nature. As the 1990s progressed, however, and more and more advanced techniques were used to sleuth out the true nature of the nebula, the astounding proved to be true — the center of the Tarantula held a cluster of stars more powerful than any yet known.

When a stellar census was finally completed in 1995 it showed more than 40 O3 stars at the center of the nebula, with a total of 3,000 stars having a mass greater than three times that of the sun. The total mass of the stars that can be measured from Earth is believed to be about 20,000 solar masses.

## Wild at Heart

At the Tarantula's heart, the immense young cluster R136 is stoked by dozens of the hottest and youngest stars known — those of spectral class O3. In the family of stars, O3s are young hell-raising roughnecks with a death wish. They live fast and furiously, tearing apart whole stellar neighborhoods with their revved up hot-rod antics, only to rapidly fade and die in ripping supernova explosions within several million years of their birth.

Many of the O stars residing in R136 are huge, weighing in at more than 100 times the mass of the sun. What's more, they maintain blistering hot surface temperatures upwards of 50,000 degrees, and may shine up to a million times brighter than the sun. Although the vast majority of these stars were created in a single burst of star formation about five million years ago, astronomers believe that the stars of R136 range in age from one million to five million years old.

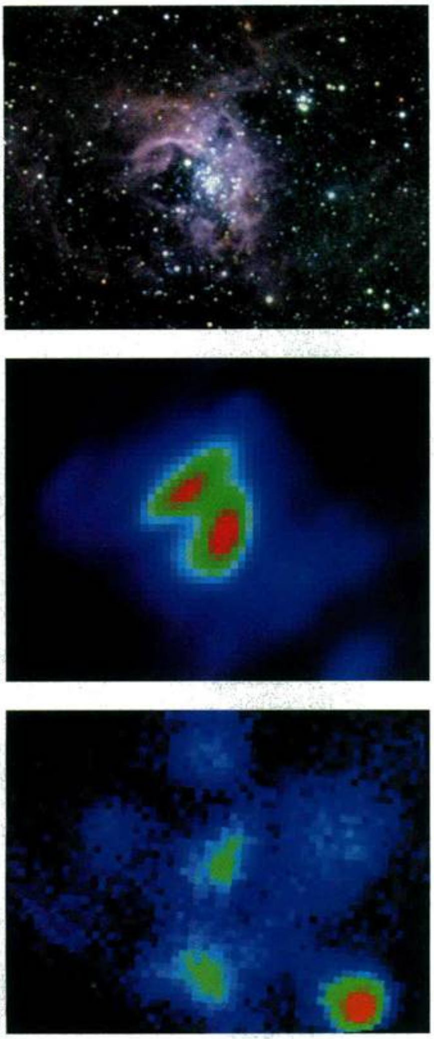
A recent stellar census of R136 counted more than 3,000 stars having a mass greater than three times that of the sun. But the total stellar population of the cluster, including stars as small as 1/10 the mass of the sun, could be as great as ten million stars — all packed into a region just two-to-three light-years across. Such a dense cluster would fit easily in the space between the sun and Proxima Centauri, our closest stellar neighbor.

## Blowing Bubbles

The first several hundred most massive stars of R136 are so blisteringly hot and luminous that they are constantly sloughing significant fractions of their mass as stellar winds billow from their surfaces. These high-energy winds stream out at speeds up to 1,800 miles per second, churning up the surrounding interstellar medium in all directions. In addition, the ultraviolet stellar sandblasting creates a cavity around the star cluster, pushing away remnants of molecular gas and dust from which the stars originally formed. "These stars at the center of the cluster are really just hammering all hell out of all of the local medium," explains Paul Scowen, an astronomer at Arizona State University who has studied the Tarantula since HST returned its first useful images almost a decade ago. Blasting winds and ultraviolet radiation have already cleared out a cavity some 25 light-years in every direction.

But this continuously expanding envelope is far from a neat circular void inside which stars live. University of Illinois astrophysicist You-Hua Chu studies how massive stars interact with the interstellar medium. "[The Tarantula Nebula] actually has many pockets — or shells — all bunched together, connected, maybe even partly-connected. Imagine a lot of soap bubbles connected together, some with channels between them that are open," explains Chu. When the intense ultraviolet radiation reaches the edge of these cavities, it blasts the surrounding gas clouds, lighting up their edges and causing walls of hydrogen 600 light-years across to suddenly shine like neon tornadoes.

Still, wind and radiation aren't the only phenomena roughing up the interstellar medium of R136. Chu and others have found evidence that supernovae have exploded in the midst of the star cluster. Although young, R136 is still old enough that many of the largest, most rapidly-evolved stars have already annihilated themselves. Concussions from these violent explosions blast through the region, creating large areas of high-energy, shock-heated material.



2MASS(UMASS/Caltech/IPAC)

IRAS

ROSAT

**Near-infrared radiation (top) is able to pierce otherwise obscuring interstellar dust, allowing astronomers to peer much deeper into the nebula's core to reveal the massive and luminous supergiant stars. In a related manner, far-infrared emission (middle) betrays the location of the photo-absorbent dust. And high-energy x rays (bottom) reveal sites of past extreme activity, such as supernovae.**

## *Nature's Red-Light Districts*

Tony Hallas

**M17 (also known as the Omega Nebula or the Swan Nebula) is one of many HII regions favored by amateur astronomers.**

Particularly young, hot, and massive stars shine with intense, high-energy ultraviolet radiation. When ultraviolet photons encounter clouds of hydrogen atoms, they literally rip the atoms apart, scattering the electrons so that only a dazed mass of hydrogen ions (protons) and free electrons remains. When the electrons and protons relax and finally get around to picking up the pieces, their subsequent reunion recreates the hydrogen atoms and releases energy in the form of radiation with a characteristic red wavelength of 656.4 nanometers. The collective force of recombination is so strong that it causes the gigantic clouds of hydrogen to shine brightly enough to be seen across vast distances.

Chu is fairly certain that this has happened in R136, although it is impossible to say where or how often. "If a supernova explodes, if the supernova ejecta hits the dense material, then you will see the signature of a supernova remnant. If the supernova ejecta does not hit any of the dense material, you won't even see it. It's really hard to categorize how many. Actually, you can't," she says. According to Penn State University astronomer Leisa Townsley, hundreds of supernovae may have occurred in the region.

That supernovae are undoubtedly influencing the Tarantula has important implications, because until now, their potential effect was overlooked in some of the most basic assumptions and calculations about conditions in the nebula.

## Got a Light?

Despite recent advances, the mechanism that sets off bursts of star formation in regions like the Tarantula Nebula remains unknown. Astronomers know that the area sits on at the tip of a molecular cloud, a tremendous pile of fuel, that extends mightily to the south of the Tarantula Nebula. But determining what might have provided the first spark is proving to be a difficult matter.

"There's an embarrassment of possibilities, but we don't yet know which is right," says Nolan Walborn, an astronomer at the Space Telescope Science Institute, who has done as much work on the Tarantula Nebula as anyone. There are three most-likely scenarios, Walborn says. The first involves large molecular clouds rapidly moving through the galaxy that collide and set off flurries of star formation.

The second possibility is that as the LMC orbits the Milky Way, it swings through the extended halo of the larger galaxy. Its movement produces a pressure shock across the front, or eastern edge, where the Tarantula Nebula sits. Consequently, this ram pressure against the large molecular cloud sets off star formation.

Finally, the third chance concerns the galactic bar of concentrated stars, gas and dust that crosses the center of the LMC. Like the bars in many irregular and spiral galaxies, the LMC's bar rotates with the galaxy, producing compression, circulation, and all sorts of turbulent interactions with the surrounding interstellar medium.

## What Next?

Like animal behaviorists charged with the task of unraveling population dynamics, astronomers are finding that the deeper they peer into the Tarantula's lair, the more interesting the nebula and its menagerie of inhabitants becomes.

The Tarantula Nebula's unique character and the place that it holds in our search to understand stars and star formation ensure that it will remain one of the most exciting objects in modern astronomy for generations. ■

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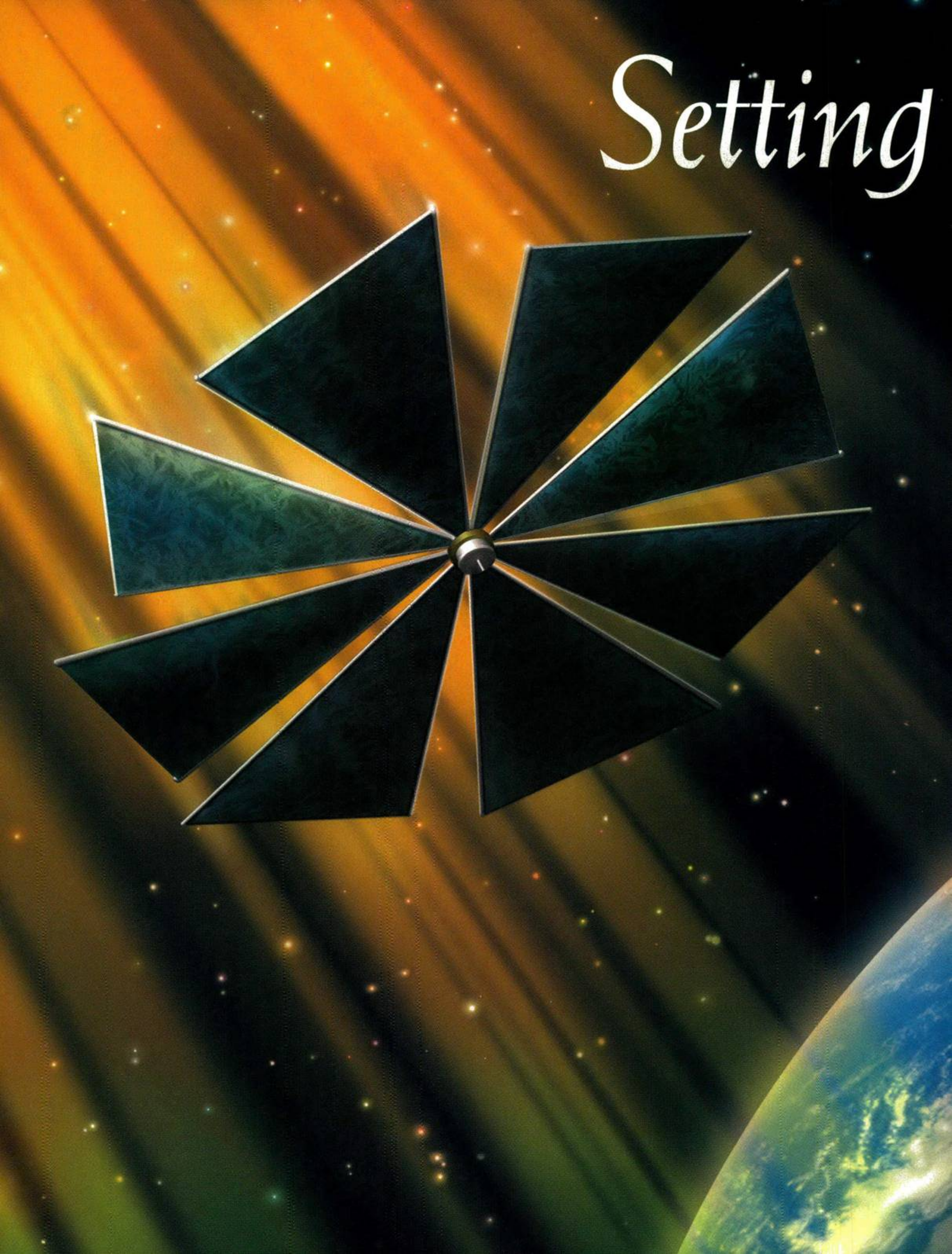
*Greg Clark is a freelance science writer living in Tucson, Arizona. This is his first article for* Astronomy.

# Setting



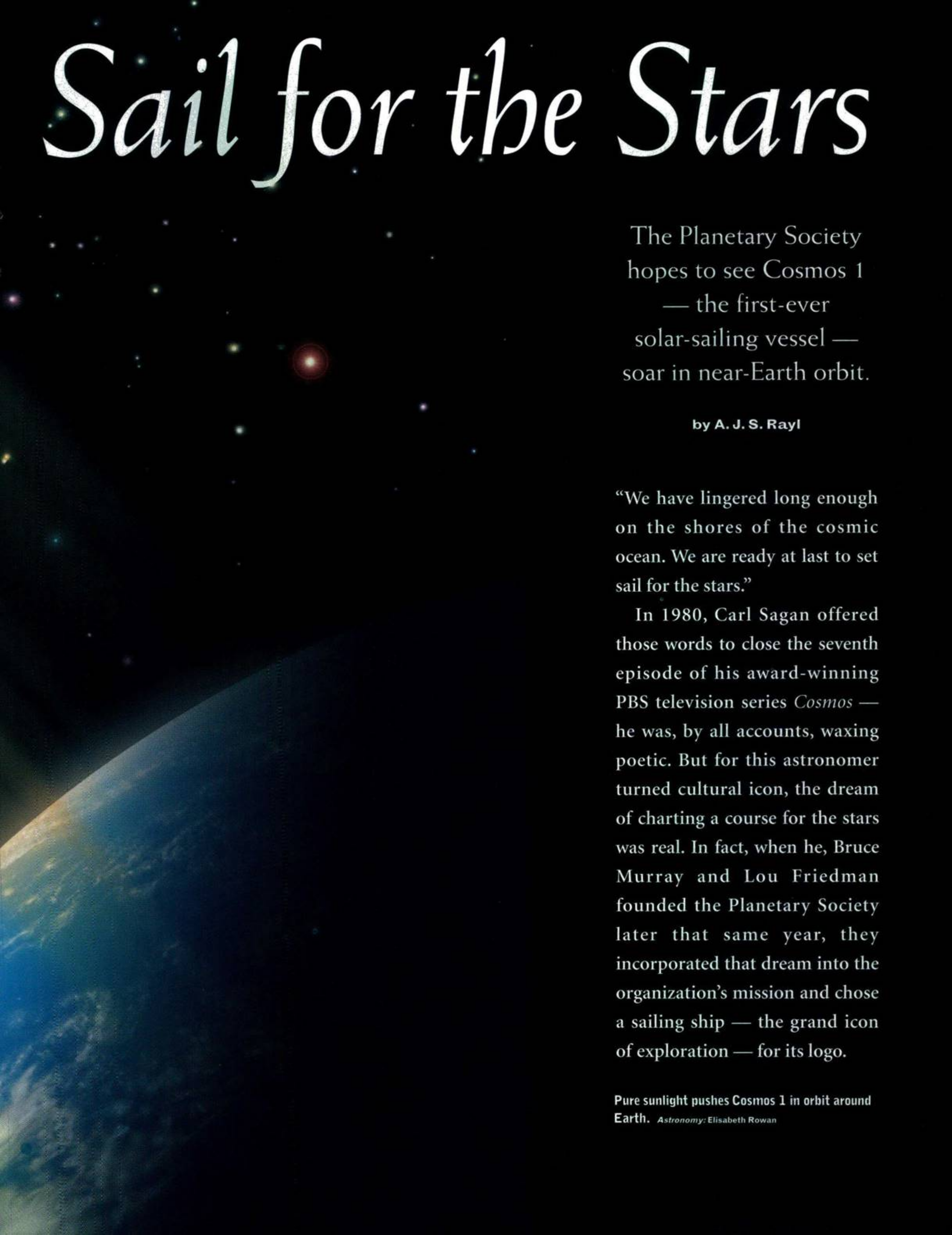
# Sail for the Stars

The Planetary Society hopes to see Cosmos 1 — the first-ever solar-sailing vessel — soar in near-Earth orbit.

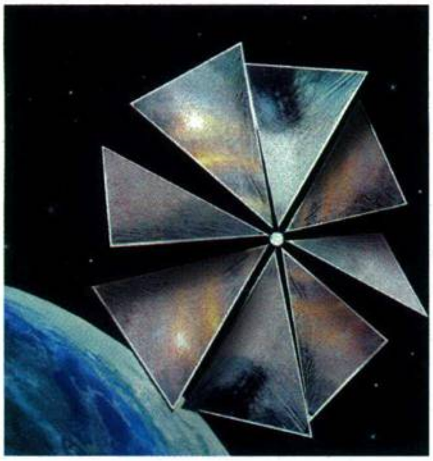
**by A. J. S. Rayl**

"We have lingered long enough on the shores of the cosmic ocean. We are ready at last to set sail for the stars."

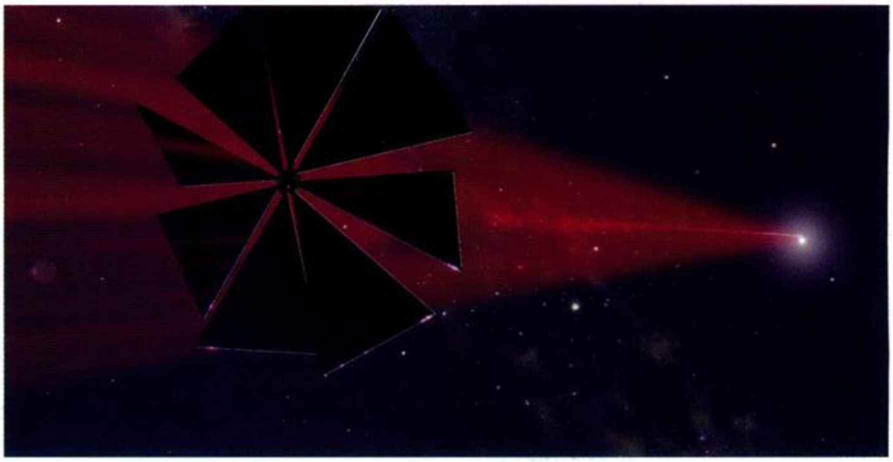
In 1980, Carl Sagan offered those words to close the seventh episode of his award-winning PBS television series *Cosmos* — he was, by all accounts, waxing poetic. But for this astronomer turned cultural icon, the dream of charting a course for the stars was real. In fact, when he, Bruce Murray and Lou Friedman founded the Planetary Society later that same year, they incorporated that dream into the organization's mission and chose a sailing ship — the grand icon of exploration — for its logo.



**Pure sunlight pushes Cosmos 1 in orbit around Earth.** *Astronomy:* Elisabeth Rowan



**A successful Cosmos 1 mission could launch a new era of cheaper, cleaner space travel and planetary exploration.** Planetary Society



**Past Jupiter's orbit, a solar-powered, high-energy laser would have to take over for the sun as a propulsive force.** Planetary Society

Now, 21 years later, if everything goes as planned, Sagan's wishes may be fulfilled. In a low-budget, high-risk venture, the Planetary Society — now the world's largest independent space organization — has spearheaded an international effort to see that a solar sail soars through space by early 2002. Although Sagan didn't live long enough to see his dream materialize (he died in 1996), his spirit fills the 88-pound (40-kg) solar-sailing spacecraft bearing the name Cosmos 1.

A unique collaboration brought Cosmos 1 into existence. The Planetary Society and the Babakin Space Center, part of the Russian Aviation and Space Agency, designed the mission. Cosmos Studios — the production company operated by Ann Druyan, Sagan's wife and longtime collaborator — is funding it. A team of Russian engineers and space scientists from Babakin Space Center, the Space Research Institute of the Russian Academy of Sciences, and the Makeev Rocket Design Bureau is building the spacecraft and will launch and retrieve it.

The directive of Cosmos 1 is simple: "Just get into orbit and sail under the power of the sun," says Friedman, executive director of the Planetary Society and one of the world's experts on solar-sailing technology. The mission's goal may be met within a few days of the spacecraft's deployment, yet the hope, of course, is that Cosmos 1 will sail on for a number of weeks, possibly even months.

"Cosmos 1 is a Kitty Hawk moment for us," says Druyan. "Remember the Wright Brothers flew their first successful airplane for only 12 seconds."

## *From Wright Brothers to Radio Shack*

Just as the Wright Brothers had no assurance they would succeed, Friedman and his international crew, including Russian physicist and space scientist Viacheslav Linkin, along with aerospace engineers Konstantin Pichkhadze, Garry Rogovsky, and Victor Kudryashov, face similar unknown territory.

And, just as the Wright Brothers put their flyer together with a modest budget, relying on available parts from their bicycle shop, this pioneering solar-sail team has done much the same. Cosmos Studios managed to pull together $4 million to finance Cosmos 1, a sum that would not even come close to covering the cost of getting the spacecraft built, much less launched, by any of the world's major space agencies. So without full governmental support, the Cosmos 1 team has had to rely on other, less propitious resources to construct the spacecraft — including the local Radio Shack for some electronic components.

Finally, and perhaps most importantly, just as the independent and impassioned Wright Brothers stood on the threshold of opening the sky, so too is the Cosmos 1 effort poised to launch a new era in space.

"In the future, space travel is not going to be entirely the monopoly of governments, and this is the first flight into that future," says Druyan, who is also producing a documentary on this first ever solar-sailing mission for Cosmos Studios.

## *Going in Peace*

For all its historic potential, this solar-sailing enterprise is also beating swords into plowshares and taking on the appearance of an international peacemaking mission. In addition to bringing together citizens from two former archenemy nations to build a spacecraft, Cosmos 1 will depend on the boost of a Russian Volna (SS-N-18) rocket, launched from a Russian nuclear submarine in the country's neighboring Barents Sea. If the Volna sounds familiar, it's probably because it is the Russian equivalent of an intercontinental ballistic missile (ICBM), designed to deliver nuclear warheads to the United States and other distant foreign targets. With a few modifications, though, this small, three-stage rocket is now expected to boost the Cosmos 1 spacecraft up into the suborbital realm at an altitude of 500 miles (800 km).

Another Russian Cold War relic will finally bump the spacecraft into orbit. Mission planners have repurposed a de-orbit motor that was designed to return Soviet spy satellites from space to an extra "kick" stage engine that will thrust Cosmos 1 into Earth orbit, just above the atmosphere at an average height of 530 miles (982 km).

The war-to-peace metaphor isn't lost on the Cosmos 1 spacecraft either. It is expected to "bloom" as tubes tucked inside the craft inflate and release eight triangular-shaped "petals," or blades — two at a time — producing a kind of disk-shaped daisy, 98 feet (30 meters) in diameter. As each petal-like sail opens, inflated tubes will jut out to support these delicate mirror-like, aluminized Mylar sails, each of which spans roughly half the size of a major league baseball diamond. Much like sails on a ship are tacked, the Cosmos 1 blades will be turned or pitched independently to reflect sunlight in different ways, thereby changing the spacecraft's course and speed — a visual that promises to redefine "flower power."

As Cosmos 1 soars across the sky it will shine brightly enough — between magnitude 0 and –5 on average, but with some flashes as bright as –10, says Friedman — that observers the world over might see it move across the sky, day or night.

Whatever its odds, the gumption and daring it took to bring Cosmos 1 even this far has imbued the solar-sailing spacecraft with an endearing quality that has the space community by and large cheering it on.

"I think everybody's pretty excited about this," says Humphrey "Hoppy" Price, manager of NASA's solar-sail technology development at the venerable Jet Propulsion Laboratory in Pasadena, California.

## *The Driving Light*

Russian scientist Fredrich Tsander is generally deemed the "father of solar sailing." In 1924, he published the first technical paper proposing to propel spacecraft with radiation pressure.

"It's a much different technology than the chemical rockets we rely on today," says Friedman, author of *Starsailing: Solar Sails and Interstellar Travel* (Wiley, 1988). "When energetic light particles, or photons, from the sun hit the surface of a solar sail and bounce off it, the photons transfer some of their momentum to the sail and give the spacecraft a thrust," he explains.

By adjusting the angle of Cosmos 1's sails relative to incident sunlight, or "tacking," the radiation pressure will add or subtract to the vessel's orbital velocity. "When we add velocity, the sail will fly away from the sun, and when we subtract, its orbit spirals inward toward the sun," Friedman informs.

Although solar sails produce very low thrust, their capacity to operate continuously will push a spacecraft ever faster, and advanced propulsion scientists hypothesize that the radiation pressure would be powerful enough to push a sail out to Jupiter. However, beyond the King of the Gaseous Giants the driving light source will have to come from elsewhere. One scenario that scientists, including Friedman, have conceived of is mighty solar-powered lasers located somewhere in a fixed orbit around Earth that would beam enough light to continue propelling the solar-sailing spacecraft.

"This would allow the craft to gain momentum in a continuous thrust that would set it on course to sail past the planets of the solar system in months instead of years, and fly to nearby stars in years instead of centuries," adds Friedman. "The most elegant aspect of the technology is that it enables long distance space travel and return trips without fuel."

Even though Cosmos 1 still must prove itself, Friedman easily imagines a not-too-distant future wherein a fleet of solar-sailing spacecraft will make up an interplanetary and, possibly, interstellar transit system. As it turns out, he's not alone in this vision.

## *Big Brother Watches*

NASA, the Russian Space Agency, and the European Space Agency all have solar-sailing projects currently in development. But this fact begs the question — why is Cosmos 1 the first solar-sailing vessel ready for launch?

ВОЛНА
БОРИСОГЛЕБСК

**A nuclear submarine-launched Volna rocket will carry Cosmos 1 into orbit.** Planetary Society

"Space agencies tend to be slow to move with new technologies," says Murray. But the Planetary Society has gained a reputation in the space community for the ability to influence — even catalyze — developments in alternative technologies for space exploration. "We established a pattern early on of picking projects that can be demonstrated well enough for the major space agencies to then pick up and run with," he adds.

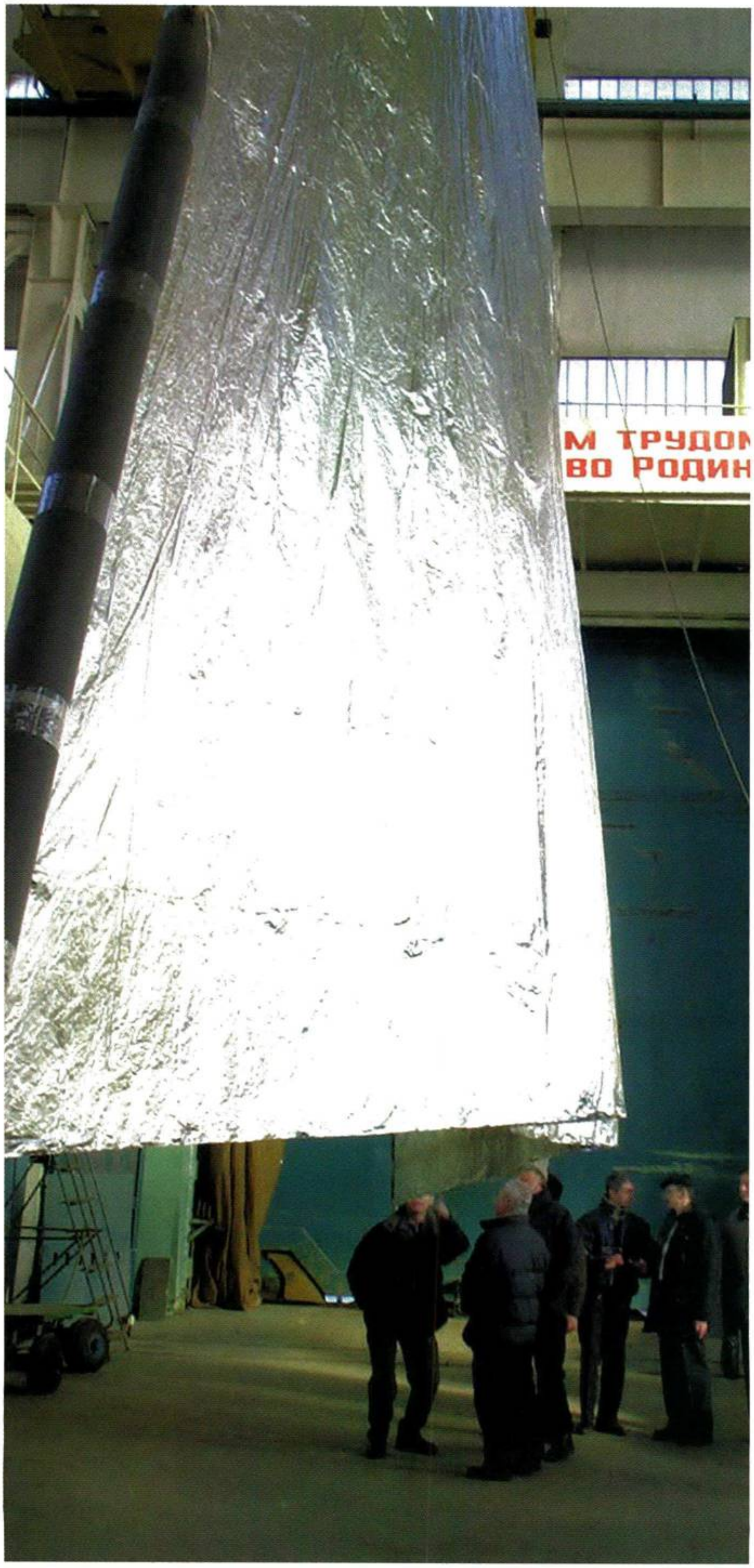
Back in the early 1990s, the Planetary Society participated in the development of a Russian-built rover for future planetary exploration. The organization sponsored a demonstration of the six-wheeled vehicle in Death Valley, California, that was impressive enough to fire up NASA's enthusiasm for its own rover technology then in the works. One result of the space agency's effort here was the celebrated rover dubbed Sojourner, which tracked across and prodded the martian landscape during the 1997 Mars Pathfinder mission.

"Really, the best thing that could come out of Cosmos 1 is for the major space agencies to invest in this technology and build solar-sailing craft," proffers Murray.

Actually, NASA has been looking into solar sailing for decades. In fact, Friedman served as the program leader for NASA's solar-sail project in the 1970s, when the technology was being considered for a rendezvous with Halley's Comet. However, because of the space agency's determination of "perceived risk," says Friedman, the project never saw the light of the sun, much less the comet.

A couple of other solar-sail attempts during the 1980s also failed to get off the ground. The World Space Foundation — a now-defunct nonprofit organization of space enthusiasts once headquartered in Washington, D.C. — funded a solar sail that was planned for test-deployment on a shuttle mission. However, then came the horrific *Challenger* disaster and NASA became much more restrictive with shuttle payloads.

The time, however, may be arriving for solar sails. "NASA is very seriously pursuing developing solar-sail technology, and we're planning a mission to launch in 2005 or 2006," says JPL's Price, noting that the agency now clearly has reason to pursue it.



NASA even considered contributing sail material for the Cosmos 1 flight in exchange for data, but the agency backed out at the eleventh hour. According to one NASA insider, political sensitivities killed this plan.

"In the end, there was just no way that NASA could allow its technology, even Mylar sails, to be used in a launch from a Russian nuclear submarine," says one source who requested anonymity. "No matter how peaceful the mission, that image was just too dicey and could too easily be taken the wrong way by the American people and others." So the Russians provided their own 5-micron aluminized Mylar material to hoist the sails.

## *Time to Test*

All systems were go for a Cosmos 1 deployment-test flight last May, during which a suborbital test craft would be launched, open two petals, and return to Earth. Then, in April, just before the deployment test, the spacecraft was damaged during a preflight checkout. A short-circuit had initiated the reentry sequence and ignited various pyrotechnic devices inside the test vehicle, resulting in damage to some of the components of the spacecraft. By June, the mission team completed the necessary repairs, and the Russian navy reserved a time slot for the submarine-based launch on July 18, 2001. Yet another delay pushed the date further back — but this time only by a day.

Finally, after months of fits and starts, at 5:33 P.M. PDT on July 19, 2001, a blast of orange and yellow flames and an ear-blasting rumble broke through the gray, overcast sky above the Barents Sea as the rocket lifted off from the Borisoglebsk, a Russian KALMAR Delta III-type nuclear submarine.

"We can see the spray of water — it looks beautiful!" Friedman reported excitedly via satellite telephone to a small group of invited guests at the Planetary Society offices in Pasadena, California, and to Druyan and her two children, who were patched in on another line from their home in Ithaca, New York.

Braving gusty winds and deck-drenching waves, Friedman and Linkin, among others, had watched the launch from the deck of a navy escort

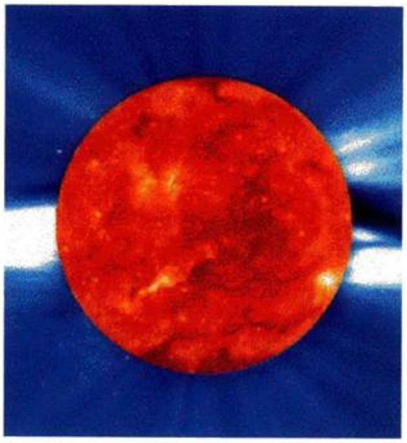
**"Zero-gravity" testing of aluminized Mylar sail at Babakin Space Center.** Planetary Society

## *In Solar Sailing, Photons Outpace the Solar Wind*

Just as wind drives sailboats out on the open water, the solar wind propels solar-sailing craft out in space. Right?

Wrong. Solar sails get their boost from pure sunlight, not the charged particles — mainly protons and electrons — that stream outward from the sun's super-hot (1,000,000+° F) corona as the solar wind.

Radiation pressure, the exertion of photons from the sun's 6000° F surface, does most of the work. As packets of energy that travel through space at the speed of light, photons are endowed with significant momentum. When they hit a reflective object, they bounce off it and transfer some of their momentum. In fact, when a photon hits the reflective surface of a solar sail, it may impart between 1,000 and 10,000 times more force — depending on the angle of the sail relative to the incident sunlight — than slower-moving, charged particles of the solar wind.



**Charged particles of the solar wind continually flow from the sun.** NASA/SOHO

However, aerospace engineers are developing so-called "magnetic sails," which would derive at least some of their kick from the electrically charged solar wind.

But don't dismay; there are some similarities between nautical and solar sailing. For example, a sailboat changes velocity (speed and/or direction) by moving at the interface of two media: the wind and water. If a gust of wind hits a rudderless sailboat, then the boat will just move willy-nilly the way the wind blows. But with the combination of wind and a rudder dipped in the water, a sailboat is forced to move along a chosen path, or tack.

A solar-sailing craft also changes velocity at the interface of two "media": radiation pressure and orbital velocity. The photons from sunlight are the equivalent of nautical wind, and the spacecraft's orbital velocity — the speed at which it orbits the sun — is the solar-sailing equivalent of having a rudder in the water. — *Paul Morledge*

vessel some two miles (3.2 km) away from the sub (closer than one can observe a space shuttle launch from Cape Canaveral). Within seconds, Friedman proclaimed: "It's gone!" The onlookers reacted with cheers, sighs of relief, and a few tears.

The test flight appeared picture perfect, but later word came that the test craft failed to separate from the rocket. It turned out to be "bad luck," Friedman contended later — a hardware glitch in the rocket.

"In the final, third-stage burn, the Volna's sensors registered too little thrust, and as a result its computers responded, as they were designed to do, and aborted the separation of the spacecraft," said Friedman.

Although the spacecraft systems were never activated, the Volna continued, as programmed, with the spacecraft still on board, to crash land where originally planned.

The problem was an apparent fluke: "Of a hundred rockets built, one is bound to be bad and we, unluckily, had that one. We could have lived just fine with low thrust from the rocket and would have gotten the test craft to an adequate altitude, but now that's somewhat irrelevant," said Friedman.

Whether or not the problem had anything to do with converting an ICBM into a launch vehicle, the Cosmos 1 team cannot say.

In any case, Konstantin Pichkhadze, the general director of Babakin Space Center, remains optimistic: "The suborbital flight provided valuable data to the project about payload integration and testing, and use of the Volna for space missions and solar-sail payload development. We are able to use these results to plan the next step in this project under the direction of The Planetary Society."

"We are confident we will be ready for the next launch," Linkin added.

### *Leaving the Shores of the Cosmic Ocean*

During the Cosmos 1 mission, American and Russian engineers and space scientists will monitor and track the solar-sailing spacecraft from the ground. Two onboard imaging cameras — courtesy of Malin Space Science Systems, located in southern California, and the Russian Academy of Sciences' Institute of Space Research — will send images of the voyage down in a near real-time basis to the Planetary Society and CarlSagan.com websites. This data will then be shared throughout the international space community.

If Cosmos 1 sails on, the mission team may attempt a couple of science experiments to demonstrate "laser sailing" for the first time — firing an Earth-based laser at the sail with just enough energy to push the sail and accelerate the spacecraft.

"And, if things keep working in controlled flight, the sail will spiral outward in an ever-increasing orbit from Earth," says Friedman.

"Solar sailing is the critical first step to two spaceflight concepts of the new century — interplanetary shuttles and interstellar flight, and this could be a pivotal moment for space exploration," Friedman says, measuring his words.

In that sense, Cosmos 1 already represents another small step in Earth's giant leap into space, and it appears destined to sail into space history one way or another. Even if the mission winds up a footnote as opposed to a chapter, the spirit behind it and the true collaborative effort shows, says Friedman.

"No matter what happens," says Druyan, "this is a first baby step toward the stars." A

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*A. J. S. Rayl is a science and technology writer based in Malibu, California.*

# sky Show

## january

Mercury shines at dusk but Saturn steals the show.

by Martin Ratcliffe and Alister Ling

▶ Mercury isn't too hard to find. For the first two weeks of January, the speedy, sun-scorched planet is in the right place at the right time. Wait until dusk, about 45 minutes after sunset, and look for a starlike object just a bit to the upper left of where the sun was right before sunset (upper right in the Southern Hemisphere). At first you might want to use binoculars, but by the second week of January, Mercury will be a snap to see with the naked eye. After midmonth, you'll see why this planet earned its mercurial reputation — it fades quickly and drops out of sight. Watch for the crescent moon hovering below Mercury on January 14, and to the planet's upper left the following night.

Locating Mars should also be easy. Face south and look halfway between the horizon and zenith to spot its bright-orange glow. At magnitude 0.7, Mars rules this sector of the sky. Despite its inviting appearance, it can be disappointing telescopically. The planet is racing to the other side of the solar system, so all you'll see is a small, 6" disk, shimmering with the most elusive of details.

By far the most eye-catching sight in the sky is a bright cluster of sparkling stars rising in the east. The ruddy giants Aldebaran and Betelgeuse and the bluish Rigel are joined this year by the steady yellow flame of Saturn. With rings wide open, Saturn will impress seasoned observers and wow beginners. Look closely for the globe's shadow cast onto the rings.

Jupiter is bright enough to mistake for a plane. Early in the evening it's a bit low in the east, so wait until it climbs up the night sky. Why? Light from objects lower in the sky are subjected to much more turbulence than that of those higher up. Night owls can rejoice that Jupiter appears at its finest around midnight.

**Taurus is an unmistakable sight above this wintertime campsite.** K. M. Harman

The moon continues to play a major role in many interesting events. First, don't forget the spectacular occultation on Friday night, December 28, when the almost-full moon slides in front of Saturn. The following two nights the moon floats not far from Jupiter. When the newborn moon returns to the evening sky on December 14, its pale-thin crescent lies one binocular field to the lower left of bright Mercury. It then slides considerably below Mars on December 18 and occults two stars in Pisces. For lucky viewers in southern Japan and equatorial Africa, the moon covers Saturn on the evening of January 24. Finally, late in the afternoon on January 26, the moon occults Jupiter for Scots and other northern Europeans.

If you're fortunate enough to live in the Southern Hemisphere or are just visiting there this month, then don't miss Comet LINEAR WM1, which will be cresting at about magnitude 4 across the deep southern sky.

Earth reaches its closest point to the sun, otherwise known as perihelion, on January 2 at 9 A.M. EST. This is when our planet is moving fastest, a bit more than 68,400 miles per hour (109,440 km/h) around the sun.

# 2002
# January

1 Jupiter is at opposition, 1 A.M. EST

2 The moon is at perigee (227,053 miles from Earth), 2:13 A.M. EST
Earth is at perihelion (91.4 million miles from the sun), 9 A.M. EST

3 Quadrantid meteor shower peaks

5 Last quarter moon is at 10:55 P.M. EST

8 Asteroid Pallas is in conjunction with the sun, 5 P.M. EST
Mercury passes 1.3° south of Neptune, midnight EST

11 Mercury is at greatest eastern elongation (19°), 6 P.M. EST

12 Asteroid Metis is at opposition, 1 P.M. EST (page 69)

13 New moon is at 8:29 A.M. EST

14 Venus is in superior conjunction, 7 A.M. EST
The moon passes 4° south of Mercury, 9 P.M. EST (page 67)

15 The moon passes 4° south of Uranus, 5 P.M. EST

18 The moon is at apogee (251,969 miles from Earth), 3:49 A.M. EST
The moon passes 5° south of Mars, 5 P.M. EST

21 First quarter moon is at 12:46 P.M. EST

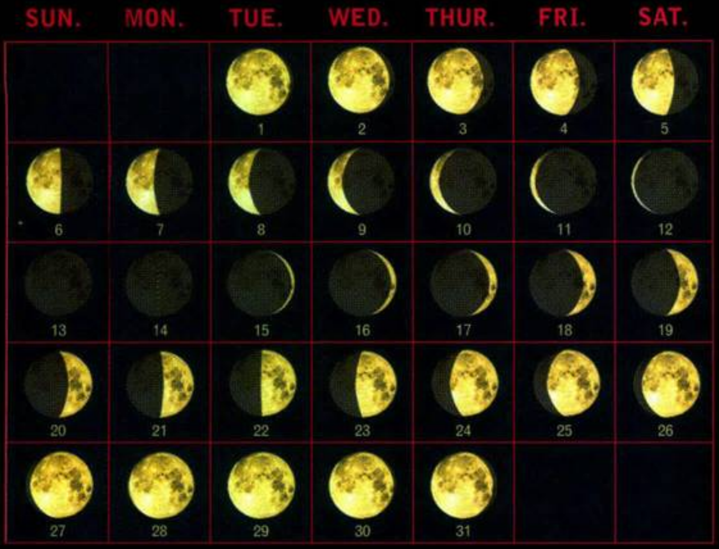
24 The moon passes 0.08° north of Saturn, 11 A.M. EST

26 The moon passes 0.9° north of Jupiter, 2 P.M. EST

27 Mercury is in inferior conjunction, 2 P.M. EST

28 Neptune is in conjunction with the sun, 9 A.M. EST
Full moon is at 5:50 P.M. EST

30 The moon is at perigee (223,691 miles from Earth), 3:59 A.M. EST


SUN.
MON.
TUE.
WED.
THUR.
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SAT.
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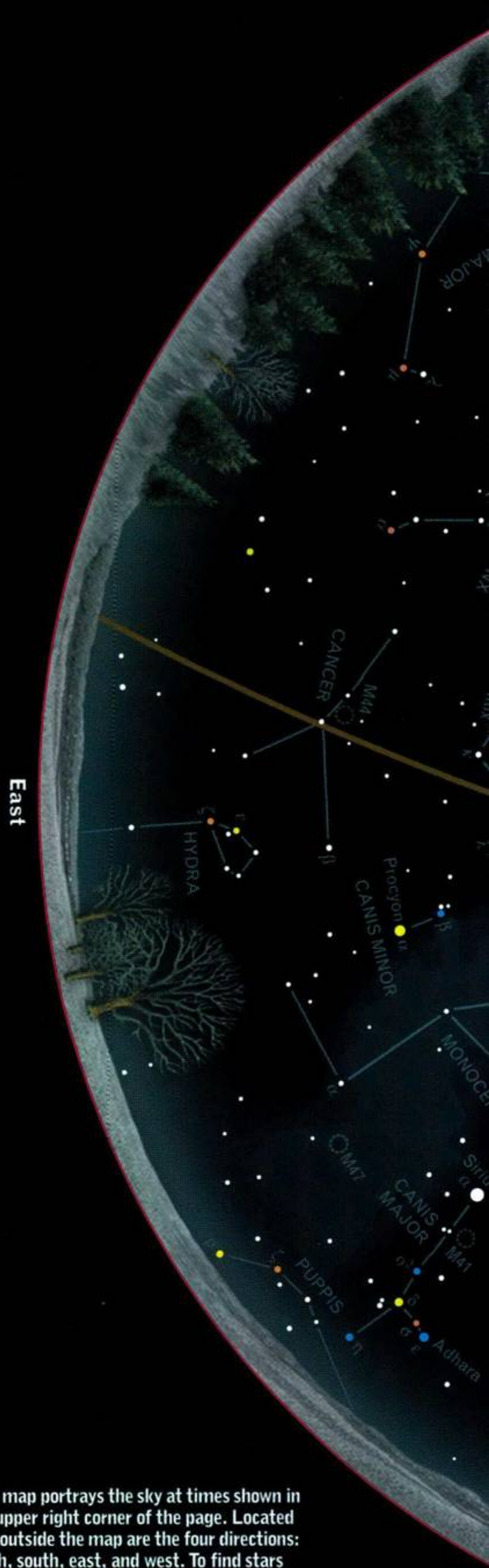
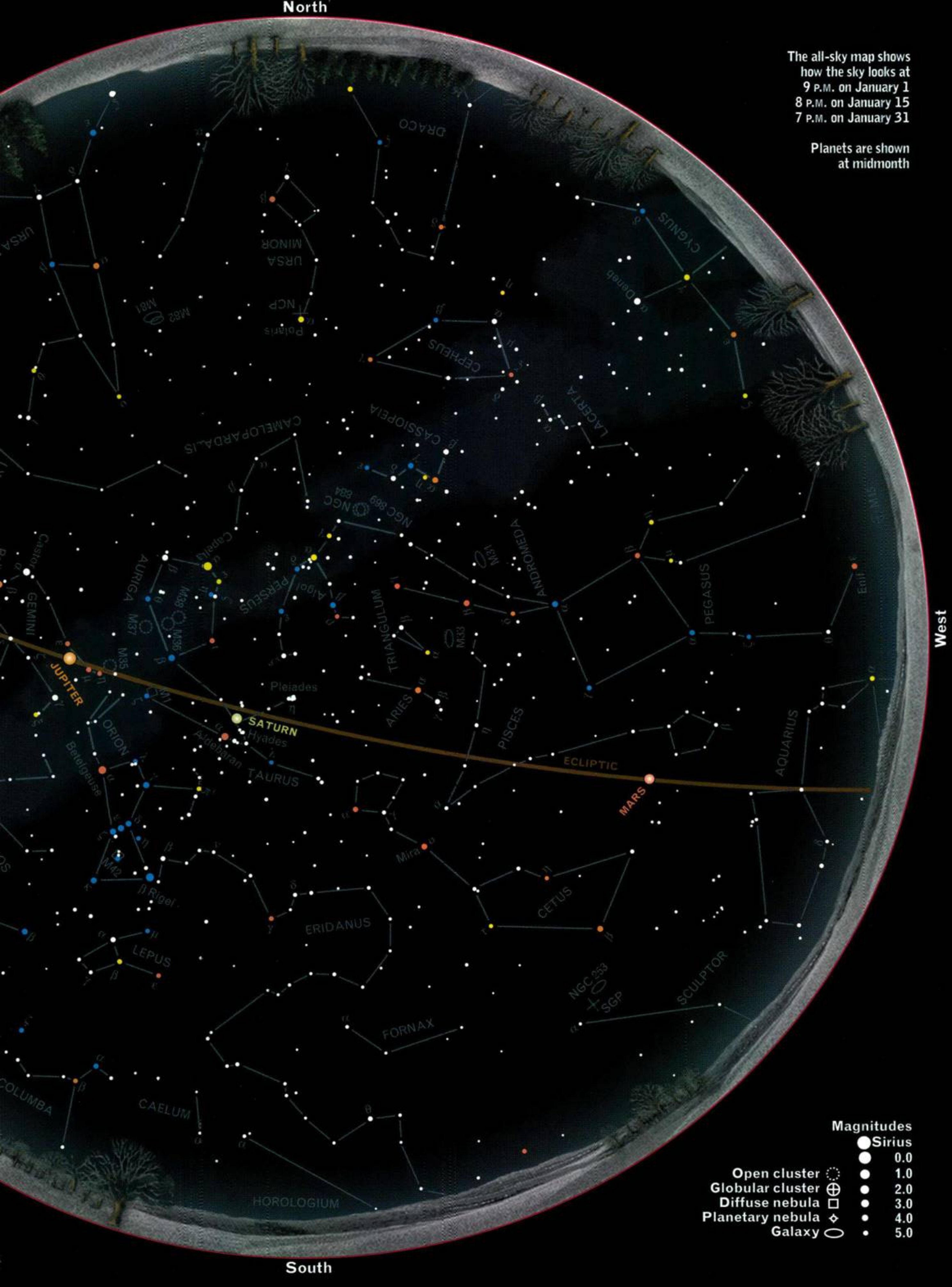

East
MAJOR
CANCER
M44
HYDRA
Procyon
CANIS MINOR
MONOCE
M47
CANIS MAJOR
M41
Siri
PUPPIS
Adhara

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

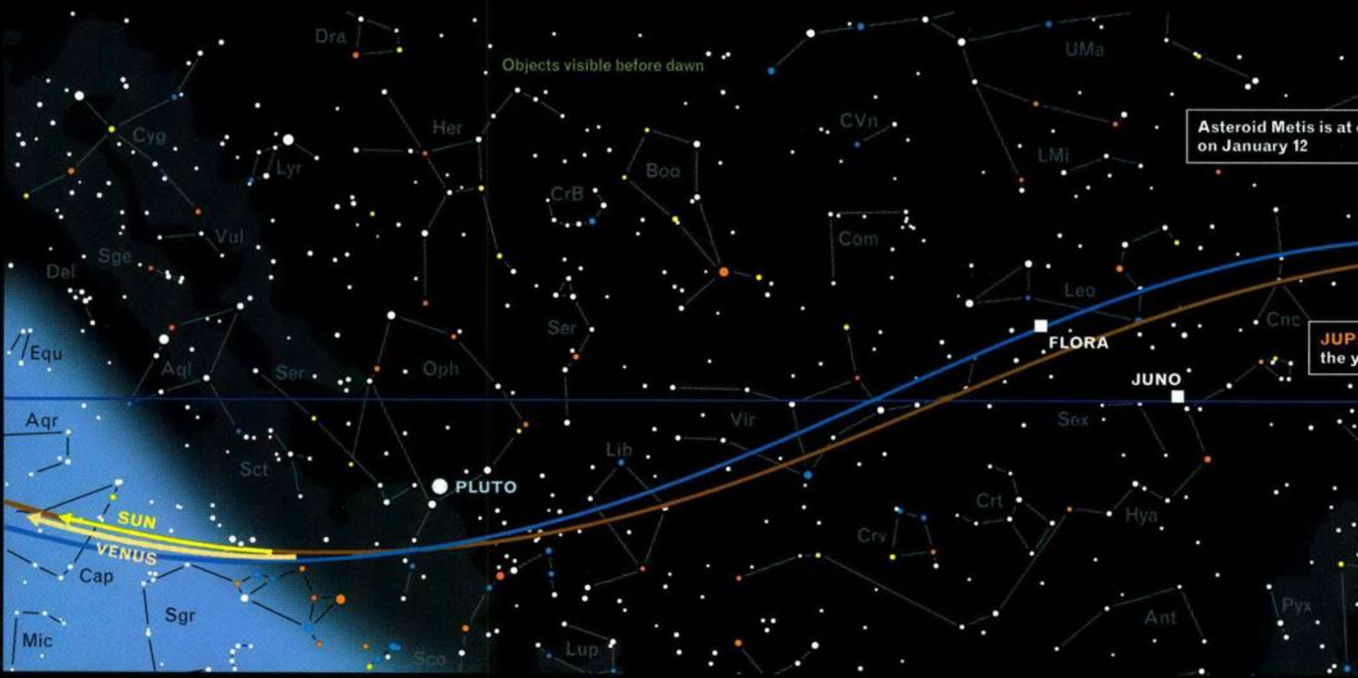

North
West
South
URSA MAJOR
DRACO
URSA MINOR
NCP
Polaris
M81
M82
CYGNUS
Deneb
CEPHEUS
LACERTA
CASSIOPEIA
CAMELOPARDALIS
NGC 884
NGC 869
M31
ANDROMEDA
PEGASUS
Enif
M15
Castor
GEMINI
AURIGA
Capella
M38
M37
M36
M35
PERSEUS
Algol
TRIANGULUM
M33
JUPITER
Pleiades
SATURN
Hyades
Aldebaran
TAURUS
ARIES
PISCES
ECLIPTIC
AQUARIUS
MARS
ORION
Betelgeuse
M42
Rigel
Mira
CETUS
ERIDANUS
LEPUS
NGC 253
SGP
SCULPTOR
FORNAX
COLUMBA
CAELUM
HOROLOGIUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
9 P.M. on January 1
8 P.M. on January 15
7 P.M. on January 31

Planets are shown
at midmonth

# Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objec


Objects visible before dawn
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UMa
Cyg
Lyr
Her
CVn
LMi
Boo
CrB
Vul
Sge
Com
Del
Leo
Ser
Cnc
Equ
Aql
Ser
Oph
FLORA
JUNO
Aqr
Vir
Sex
Lib
Sct
PLUTO
Crt
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VENUS
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Asteroid Metis is at
on January 12
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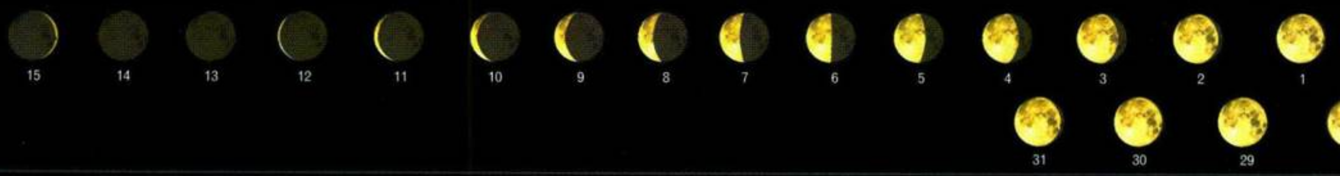
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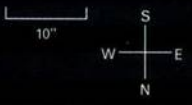
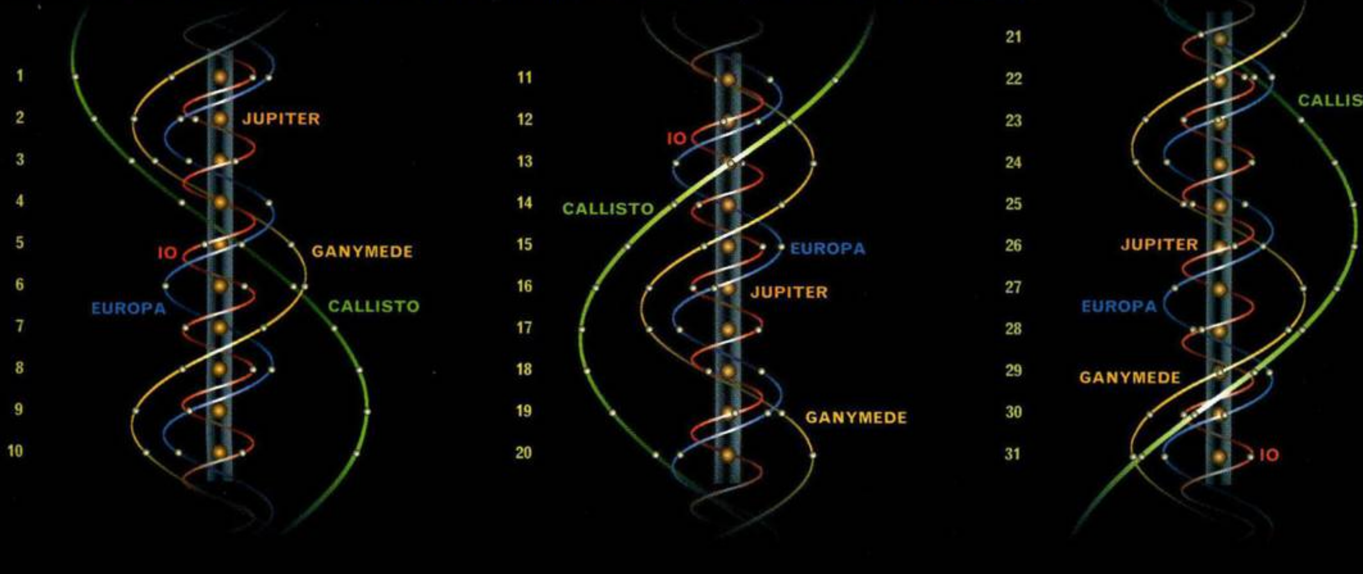
3
2
1
31
30
29



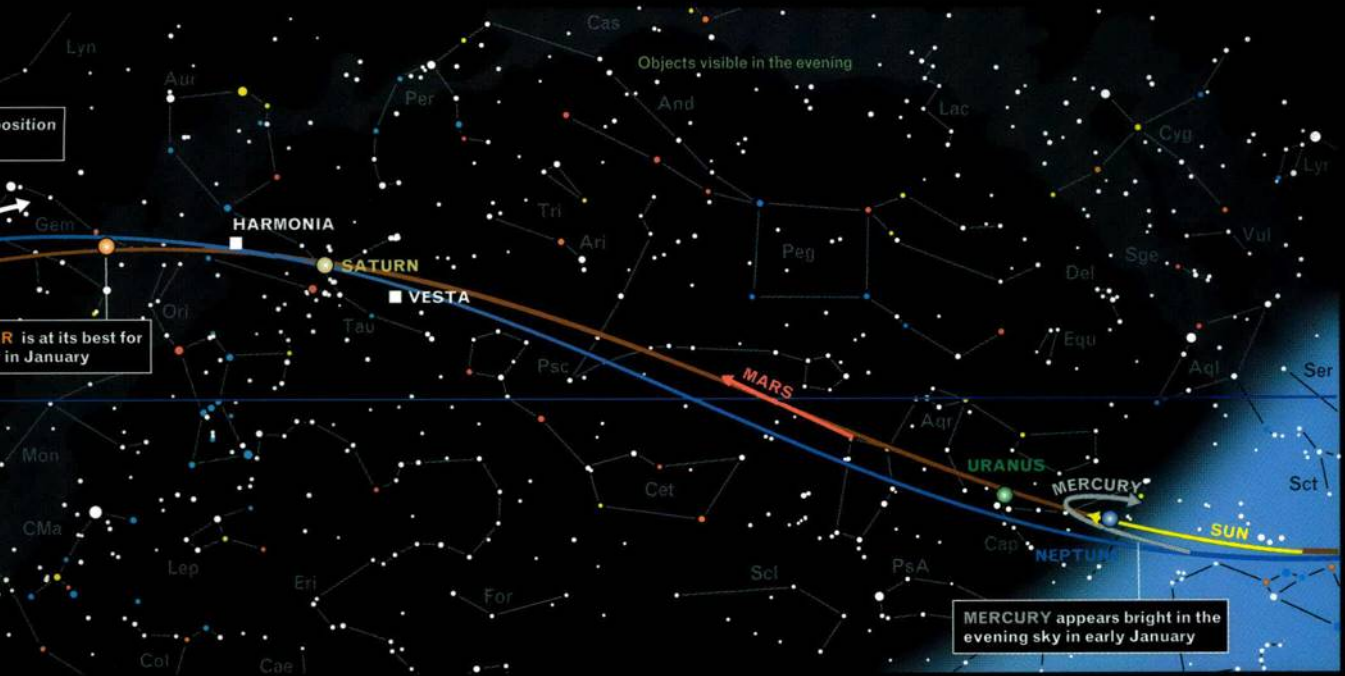
| **PLANETS** | **MERCURY** | **MERCURY** | **VENUS** | **MARS** | **JUPI** |
|---|---|---|---|---|---|
| **Date** | January 1 | January 15 | January 15 | January 15 | Janua |
| **Magnitude** | −0.8 | −0.3 | −3.9 | 0.9 | −2 |
| **Angular Size** | 5.5'' | 7.5'' | 9.8'' | 5.9'' | 46. |
| **Illumination** | 87% | 45% | 100% | 90% | 100 |
| **Distance (AU) from Earth** | 1.230 | 0.900 | 1.711 | 1.600 | 4.2 |
| **Distance (AU) from Sun** | 0.384 | 0.314 | 0.728 | 1.440 | 5.1 |
| **Right Ascension (2000.0)** | 19h51.8m | 21h02.4m | 19h47.4m | 23h50.0m | 6h38 |
| **Declination (2000.0)** | −23°03' | −16°50' | −22°03' | −1°33' | 23° |

# Jupiter's Moons

Dots display positions of Galilean satellites at 10 P.M. EST on date shown. South is at top to match the view in a telescope.



luring the month.


Lyn
Cas
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Per
And
Lac
Cyg
Lyr
Gem
HARMONIA
SATURN
VESTA
Tri
Ari
Peg
Vul
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Del
Ori
Tau
Psc
MARS
Equ
Aql
Ser
Mon
Aqr
URANUS
MERCURY
Sct
Cet
SUN
CMa
Cap
NEPTUNE
Lep
Eri
For
Scl
PsA
Col
Cae

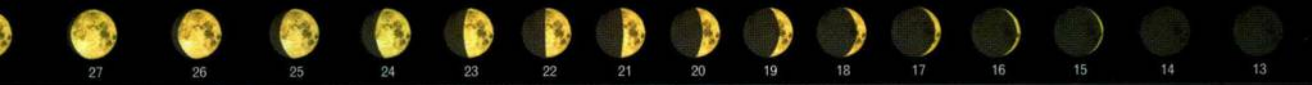
Objects visible in the evening

osition

R is at its best for in January

MERCURY appears bright in the evening sky in early January

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.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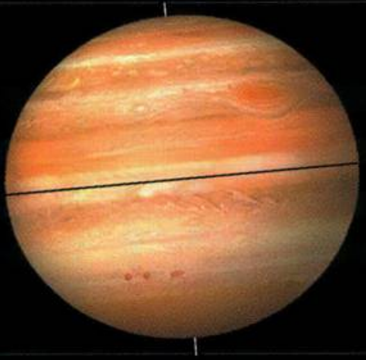
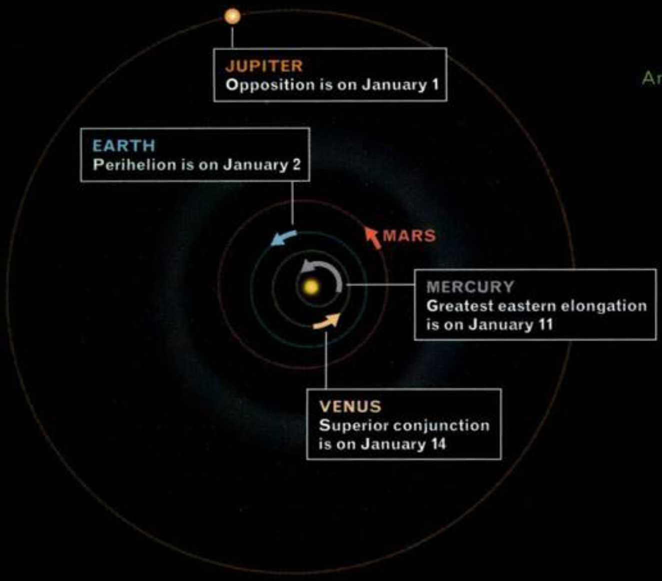


| SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|
| January 15 | January 15 | January 15 | January 15 |
| −0.2 | 5.9 | 8.0 | 13.9 |
| 19.9" | 3.4" | 2.2" | 0.1" |
| 100% | 100% | 100% | 100% |
| 8.351 | 20.848 | 31.052 | 31.222 |
| 9.061 | 19.989 | 30.095 | 30.466 |
| 4h28.4m | 21h42.8m | 20h41.3m | 17h05.3m |
| 20°00' | –14°28' | –18°11' | –13°01' |

## The Planets in Their Orbits

Arrows and dots show planets' positions during the month.

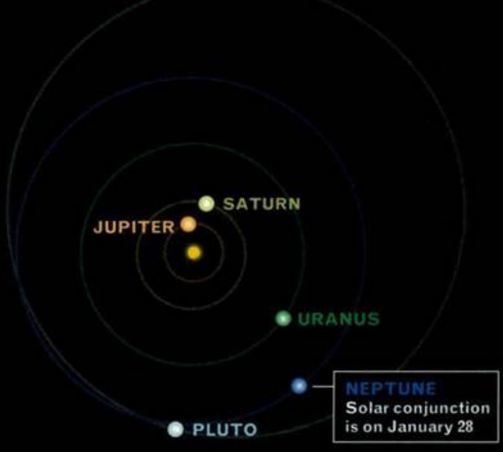


**JUPITER**
Opposition is on January 1

**EARTH**
Perihelion is on January 2

**MERCURY**
Greatest eastern elongation is on January 11

**VENUS**
Superior conjunction is on January 14


SATURN
JUPITER
URANUS
PLUTO

**NEPTUNE**
Solar conjunction is on January 28

**Golden Gamma Andromedae Leads the Way**

It's nice to return to one's roots every now and then. From my suburban driveway, I've used my first-ever telescope, a 4.5-inch Newtonian, to contact the sky. This trusty old scope is easier to use now with its new Dobsonian mount, 1.25" eyepieces, and a red dot LED finderscope — I'm observing more with it now than ever before.

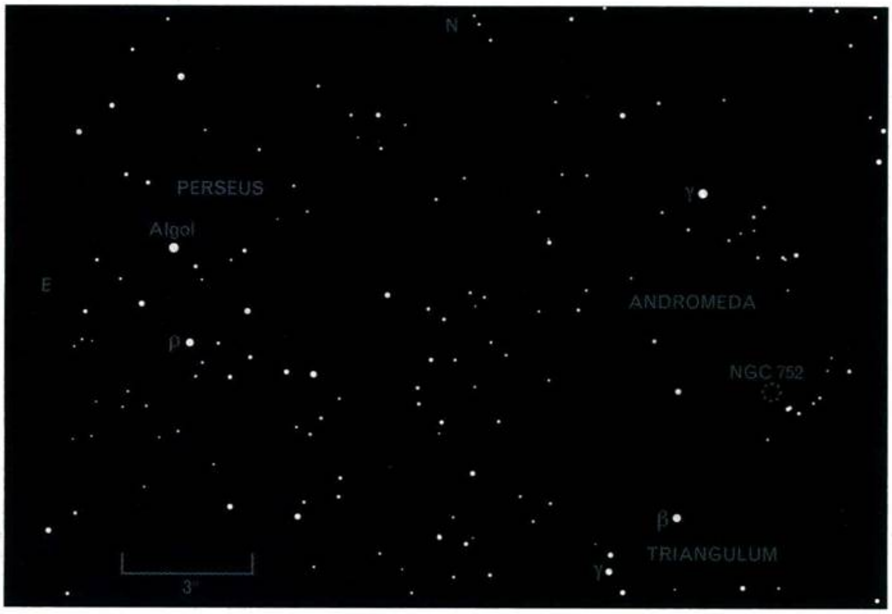
Gamma (γ) Andromedae is one of the sky's loveliest doubles for even those who are using smaller telescopes. At a magnification of 30x, it's tough to separate the fainter blue component from the glare of the brighter one. But at 130x, it's easy to see the gap of 10".

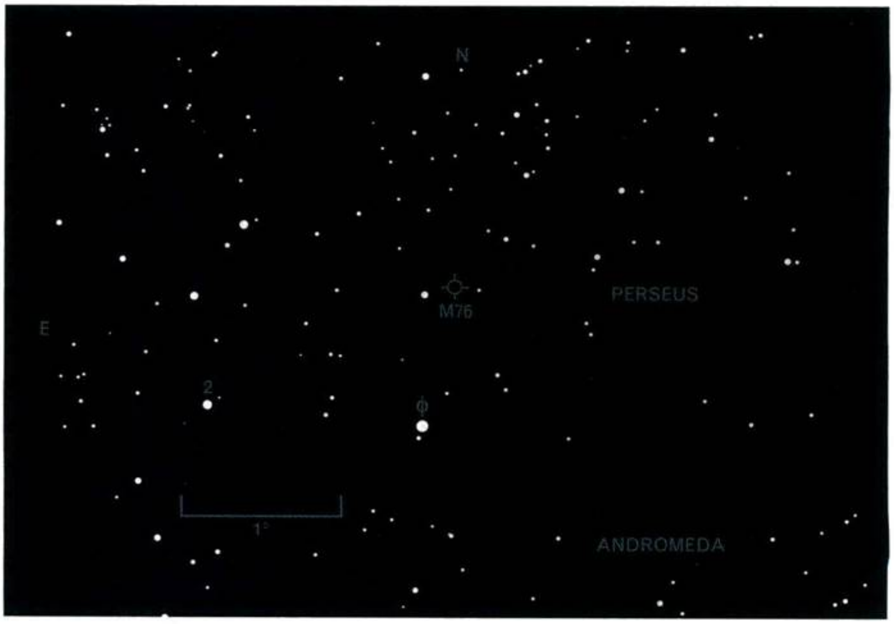
Another golden star nearby, well known to deep-sky observers, lies on the edge of open star cluster NGC 752, one binocular field south of Gamma And. In fact, from a dark rural site, NGC 752 is best seen with binoculars because it's almost twice the apparent size of the moon. Through my scope in the city, the cluster is a random splattering of stars of similar brightness. What makes it a nice observing target is the bright pair on its southern side, the westernmost component that appears a lovely yellow.

A quick hop across the Andromedan border brings you to Rho (ρ) Persei, just below the famous eclipsing binary star Algol. Rho Per is an irregular variable that does not fall into any other class, but as a variable nonetheless, it may reveal its reddish side. Through my small scope it appeared to be a rich golden color.

It comes as a surprise to many observers that M76 (NGC 650–1) — a planetary nebula in Perseus just a short hop from Gamma And — is by no means the toughest object to find on the Messier list. Sure, it's small and quite challenging, but I found it with my 4.5-inch scope with the full moon behind the house and two annoying streetlights shining close by.

The first step in tackling such a challenge is to examine a good sky map. Starting at the bright star Phi (ø) Persei, hop north a bit more than a moon-width to a magnitude 6.7 field star. Match the chart to the orientation you see. If you use a diagonal, then photocopy the chart, flip the copy over, and shine a flashlight through it from below.





Next, you're going to need to boost magnification to 100x or more so that you're concentrating on both that star and a magnitude 9.5 star to the west. Higher power darkens the field a bit, which helps increase the contrast. If the streetlights near you are anything like those near me, you'll need to use a hooded jacket or dark towel to block out some of the glow.

Finally, take a deep breath so as to avoid fogging the eyepiece, try to relax, and jiggle the scope — our peripheral vision is wonderfully sensitive to faint moving objects. If you need another breath, turn to the side to exhale while keeping your observing eye closed. That's what it took for me to see M76's pale blob. From dark rural skies with a big scope, M76 is one of my favorite objects with its two distinct lobes — thus its name Little Dumbbell Nebula.

### Two Giants Loom Large

Jupiter and Saturn continue to dominate the nighttime sky, while Mars fades from magnitude 0.7 to 1.0 as it slowly falls behind the sun from our earthly vantage point. Speedy Mercury also makes a brief appearance in the western sky after sunset.

On New Year's Day, **Mercury** shines at magnitude –1.0, the brightest for the month, but stands only 15° east of the sun. This places Mercury very low to the horizon at twilight and, consequently, difficult to see. Try scanning the horizon after sunset (not before, because you may catch a glimpse of the sun and damage your eyesight). On January 9, Mercury passes 1.3° south of Neptune, an event of purely cerebral interest because Neptune is far too dim to see in twilight. By January 11, Mercury lies 19° east of the sun, its greatest elongation for this month, but it has also dimmed to magnitude –0.6.

Viewing a young moon, just hours after new, makes for a great challenge. On the evening of January 14 in America, try to glimpse the 32-hour-old moon — it'll lie 5° southwest of Mercury and shine at magnitude –0.2. The moon stands a mere 3° above the west-southwestern horizon one-hour after sunset and sets just minutes later. In the days following, Mercury falls quickly back toward the sun — revealing to those using telescopes an ever-narrowing crescent as it heads toward a passage between Earth and the sun.

**Mars**, prominent among the dim stars of Aquarius, appears in the western sky after twilight has passed. The darker sky reveals Mars easily. The planet then passes into Pisces on January 8, and stands 5° north of a growing crescent moon on January 18. Its 6" disk reveals very little through a telescope now.

On the same night, the moon hides the magnitude 4.6 double star 33 Piscium in a lunar occultation for observers in the northwestern half of the United States. The full and dramatic disappearance of 33 Piscium will be visible from locations north of a line between California and Montreal, Canada. Observers located "on" the line will see a partial occultation, with the star alternately disappearing behind mountains and reappearing between the valleys along the limb of the moon. Such spectacular "grazing occultations" will be the brightest for a long time, and should provide a wealth of information to scientists attempting to build a detailed picture of the relatively unknown limb regions of the moon. They're also superb projects for astronomy clubs whose observers can be strung out along a two-mile-wide track, with their combined observations building a detailed outline of the limb of the moon. The occultation can be viewed either by the unaided eye, binoculars, or a video camera. You can more accurately time the event by using a shortwave radio tuned to a time-signal broadcast by a station such as WWV Fort Collins (2.5, 5 and 10 MHz). For more details on this graze and other occultations, including how to use a camcorder to record such occurrences, connect to www.lunaroccultations.org.

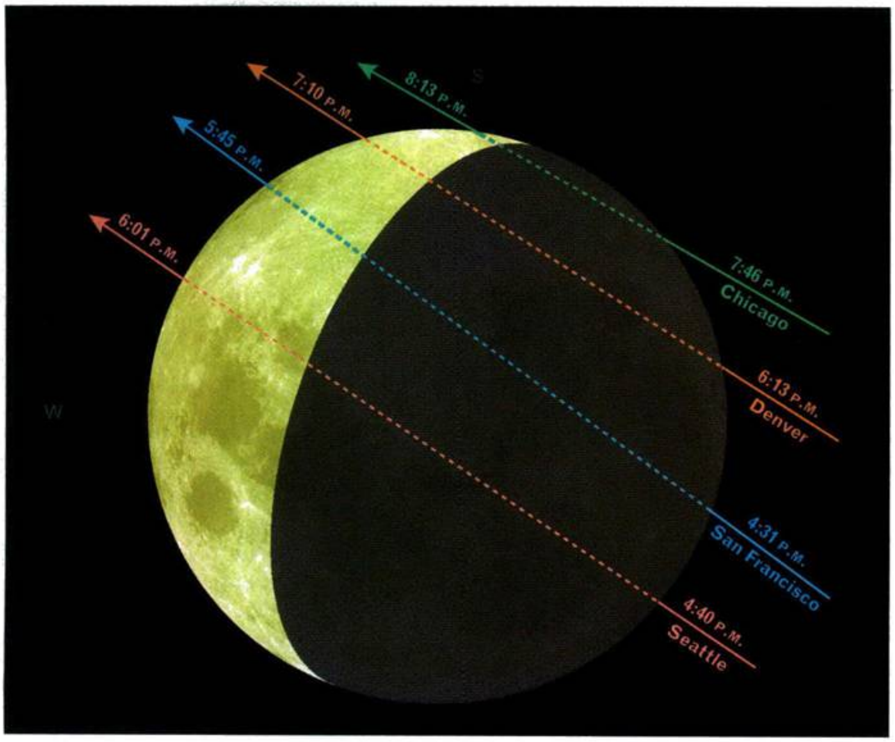
**Saturn** reached opposition in early December, and now stands clear of the eastern horizon after sunset. Its spectacular placement among the stars of Taurus the Bull commands attention. Saturn's retrograde, or westerly, motion relative to the background stars slows to a halt, leaving Saturn located near one of the points of the V-shaped Hyades star cluster. Aldebaran, sparkling at magnitude 0.9, lies 3.6° south of Saturn, shines almost a magnitude brighter than the Ringed Planet.

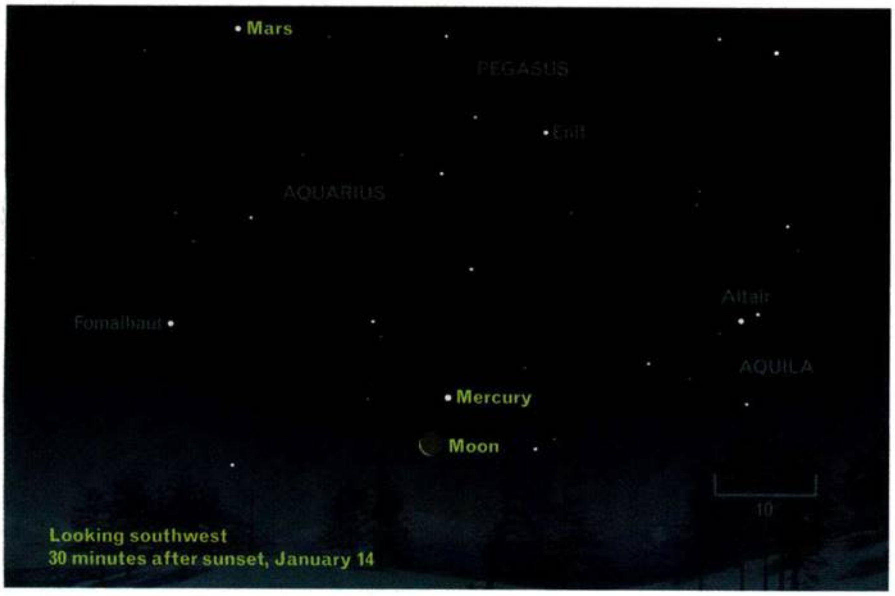
**Catch a glimpse of Saturn's three prominent ring systems this month.** Jim Rouse

Through a telescope Saturn's appearance is second to none. Its gossamer-thin ring system dazzles even veteran observers. Small telescopes 2.5 inches (60mm) in diameter can reveal structure in the rings. Most prominent is the 2,500-mile-wide Cassini Division, named after its discoverer, Italian astronomer Giovanni Cassini. The division separates the main A and B rings that are visible in most amateur scopes. Spacecraft images reveal that the rings constitute thousands of little ringlets, but none of these is visible in small scopes. The inner, or C, ring, also referred to as the Crêpe Ring, is duskier than the first two rings and represents the last of the three principal rings visible to amateurs. Currently we are viewing the southern face of the rings and will continue to do so through 2009.

The disk of Saturn is flattened at the poles by about 10 percent, noticeable to everyone who views the planet through a telescope. This flattening results from the rapid 10-hour rotation of Saturn. Features in the planet's atmosphere are subtle at best.

Keeping track of the number of saturnian moons is becoming rather like keeping score of a basketball game. The current count is at least 28, although the exact count depends on when you ask because of ongoing discoveries. However, some of the moons have been known for some time. Titan, the largest and brightest moon, shines at magnitude 8.4 and takes nearly sixteen days to orbit Saturn. On January 5 it stands to the east of Saturn. Eight days later it lies to the west of the planet, and so on. (See "Meteors and Moons" for more information on Saturn's moons.) In the pre-dawn hours of December 28, the moon occults Saturn for observers in Hawaii and North America. Approximate times for disappearance for eastern, central, and western United States are at 4:00 A.M. EST in New York, 2:40 A.M. CST in Kansas City and 12:10 A.M. PST in Sunnyvale, California. A similar event happens again on January 24 for observers in a region from equatorial Africa across to southern Japan.





Looking southwest
30 minutes after sunset, January 14

As soon as the sun sets, **Jupiter** stands above the eastern horizon, below and to the left of Saturn, looking like an approaching aircraft with its landing lights on. Shining at magnitude –2.7, Jupiter lies at opposition to the sun on New Year's Day. It dominates the constellation of Gemini the Twins, beginning January in the center of the constellation.

For observers in northern Europe and northern England and Scotland, the moon occults Jupiter on January 26. For the northern British Isles, the event takes place as twilight begins. All four Galilean moons lie to the east of the planet and so will be progressively occulted. The main Jupiter event takes place before 6 P.M. local time in Scotland, but times vary at other locations. Observers across parts of northern England will see Jupiter partially occulted by the moon in a spectacular grazing occultation.

Jupiter's opposition also means that it lies closest to Earth for the year at four astronomical units (1 AU = 93 million miles). At this time, Jupiter also appears at its largest through a telescope. Its relatively large size of 47" provides for spectacular views of its turbulent and cloudy atmosphere. The Great Red Spot makes frequent appearances during the month, beginning on January 1, when it is on view from Earth in the late evening. Jupiter's fast rotation of less than ten hours carries the Red Spot and other features out of view within hours, constantly revealing a new face to us. It's these dramatic changes, as well as changes in the features themselves, that makes Jupiter so fascinating to observe closely. Jupiter is visible all night during January.

**Venus** is currently invisible due to its conjunction with the sun, but will reappear in the evening sky this spring.

# Meteors and Moons

**Quadrantid Meteor Shower**

The moon is at a waning gibbous phase on January 3, making observations of this year's Quadrantid meteor shower rather difficult. Look for the shower in 2002 when it occurs during a new moon.

**Viewing Maestlin R**

A relatively obscure feature on the moon, which is often hidden by rays emanating from the bright crater Kepler, is the ancient and almost buried crater Maestlin R. Find this target adjacent to the tiny 5-mile-wide crater Maestlin, named after the German astronomer and mentor of Johannes Kepler. The visual appearance of Maestlin R at low angles of illumination can be striking. As a small arc of individual peaks, each drops long shadows across the lava fields of Oceanus Procellarum. A longer ridge arcing to the northwest of the feature indicates the earlier presence of a 40-mile-wide crater, but floods of lava have almost completely buried it. Watch the region carefully on the night of January 25, just after sunrise on Kepler, and the long shadows should form.

**Saturn's Satellites**

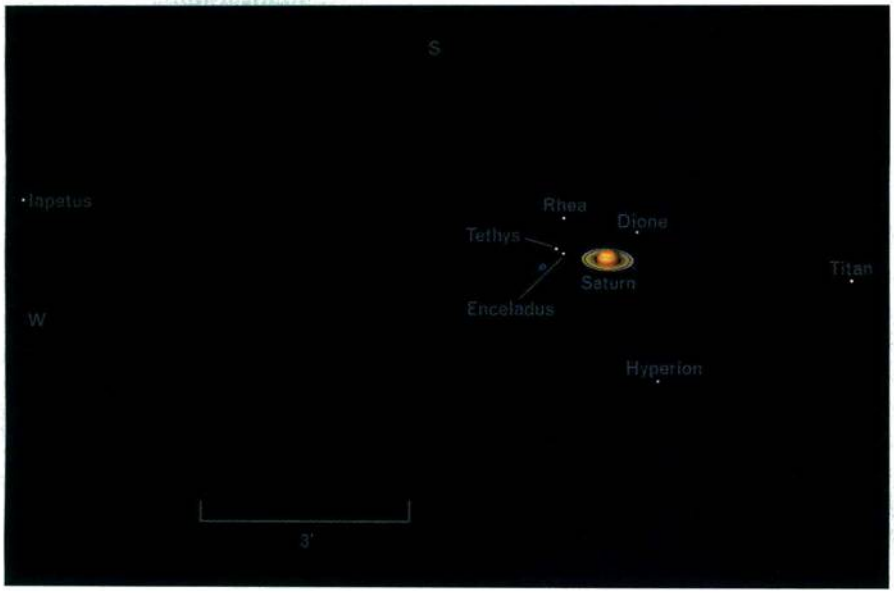
Iapetus, the enigmatic variable moon of Saturn, will be at its brightest during January. It has been brightening during most of December as it moves toward its western elongation when it shines nearly two whole magnitudes brighter than at its eastern elongation. In early January it shines at magnitude 10.2. Six weeks later it will dim to magnitude 11.9. You can compare its magnitude to those of the other saturnian moons. Tethys, the brightest of the inner moons aside from Titan, shines at magnitude 10.2. Enceladus, more difficult to spot, shines at magnitude 11.7. Finding Enceladus requires at least a 6-inch scope, but it's much easier to identify when it lies near Tethys. On January 4, the pair is very close to each other, with Enceladus shining dimly just a little closer to Saturn than Tethys.

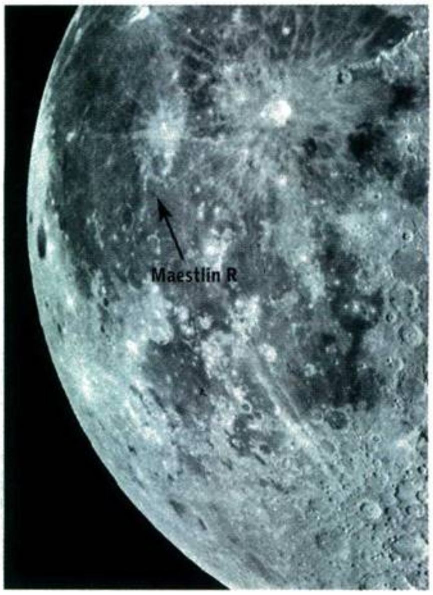
**Galilean Treats**

The four Galilean moons are visible at various times of the night, and occasionally some will undergo eclipses behind Jupiter or transits in front of the planet. The farthest moon of the four large ones is Callisto, and jovian eclipses of it are rare. During Jupiter's 12-year orbit around the sun, only two series of eclipses involving Callisto occur. The current series began last September and continues until September 2004, and only 66 eclipses will occur in this time frame. Two eclipse sequences occur in January in addition to two transits. The events listed above are given in Eastern Daylight Time. IV = Callisto; Tr = transit; Oc = occultation; Sh = shadow transit; Ec = eclipse; D = disappearance; R= reappearance; I = ingress; E = egress. The events are worth viewing due to their rarity. Only some are visible in the United States.

## Catch Callisto

| 2002 | | |
|---|---|---|
| **Jan. 5** | 12:06 | IV.Oc.D. |
| | 15:57 | IV.Ec.R. |
| **Jan. 13** | 20:57 | IV.Tr.I. |
| | 23:36 | IV.Tr.E. |
| | 23:58 | IV.Sh.I. |
| **Jan 14** | 02:49 | IV.Sh.E. |
| **Jan. 22** | 02:18 | IV.Oc.D. |
| | 05:00 | IV.Oc.R. |
| | 07:11 | IV.Ec.D. |
| | 10:09 | IV.Ec.R. |
| **Jan. 30** | 11:27 | IV.Tr.I. |
| | 12:07 | IV.Tr.E. |
| | 17:59 | IV.Sh.I. |
| | 21:01 | IV.Sh.E. |





**A small arc of peaks rings part of the ancient crater region Maestlin R.** Lee S. Najman

### Pollux Anchors Asteroid 9 Metis

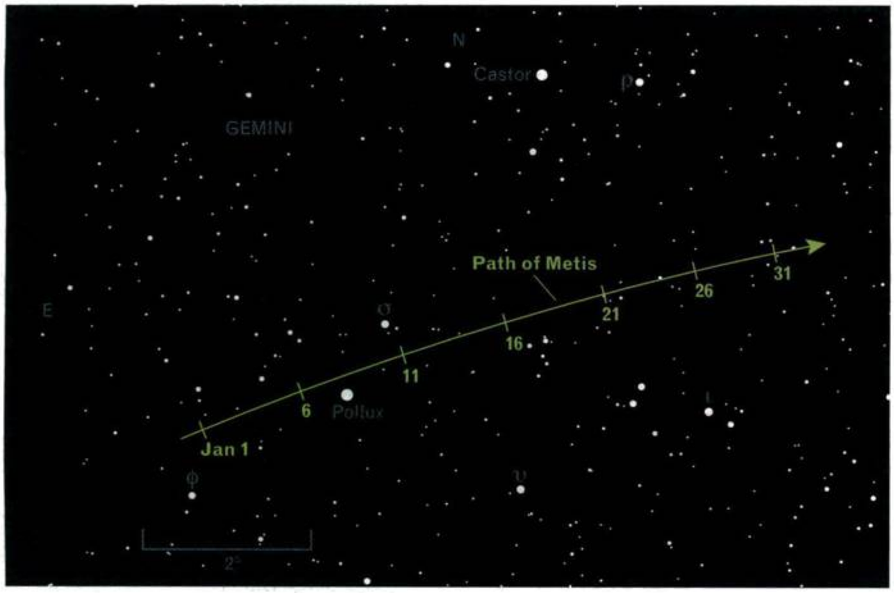
Hide-and-seek is the main game of asteroids. Supreme observer William Herschel dubbed them "asteroids" because they mimicked the stars. ("Asteroid" means "resembling a star.") When you know where to look, these orbiting heaps of space rock aren't that hard to pin down. In fact, you can glimpse the brighter ones, such as 9 Metis, from your driveway while you're waiting for your scope to cool down.

To find Metis, set your sights on Pollux, one of Gemini's bright stars rising in the east. In fact, from January 7 to 9, Metis appears less than 30', one lunar diameter, to the northeast (upper left) of Pollux. If you can't remember which one is Castor and which one is Pollux, then use Ken Hewitt-White's alphabetic mnemonic: "Castor is close to Capella, and Pollux is closer to Procyon."

It's fascinating to try to picture what Metis might look like. Eros is now the most familiar asteroid thanks to more than a year's worth of up-close imagery. At 230 miles (370 km) across, Metis is almost 10 times the size of Eros. As a result, it's more likely potato-shaped instead of Eros's banana-like configuration. It is likely riddled with craters, because studies indicate that an asteroid's life is full of collisions with smaller space rocks.

**The double-lobed planetary nebula NGC 2371–2 always proves a lovely sight** J. C. Mirtle

With an accurate computer-generated chart, it's both a snap and great fun to spot several asteroids in a given evening. In fact, some people get hooked on it. I get the most enjoyment from watching them move over the course of an hour or two. On January 3, Metis skirts only 5' south of a star of similar brightness. On January 10, it's 5' north of a magnitude 8.9 star. Metis comes even closer to other stars toward the end of the month.



If you have a big scope, look through it on January 27, when Metis lies a mere 2' from the double nodule planetary nebula NGC 2371–2. The name Metis stems from one of the more curious segments of Greek myth, wherein the goddess Metis boasted to Zeus that she would bear him a son mightier than he. Arrogant as ever, Zeus decided to swallow her, and as a result, the goddess Athena sprouted right out from his head!

### Comet LINEAR WM1 Peaks Down Under

If you're south of the equator, make sure to scan the constellation Indus as dusk loses its evening colors. It's likely that you'll see a nice 4th-magnitude comet with a tail, similar to June's LINEAR A2 apparition. LINEAR is an acronym for Lincoln Near-Earth Asteroid Research, a robotic telescope. ◼

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*Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.*

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Published in Canada by Penguin Books at $34.99.

# The Making of an Aurora

*A new book details the quirky story of how Norwegian researcher Kristian Birkeland followed his own light path to unlock the secrets of the aurora borealis.*

During the years Kristian Birkeland had worked on the nitrogen furnace, he had not had time to analyze the results of his Aurora Polaris Expedition or to publish scientific papers. He decided that it was time to plan a major scientific treatise, based on these new data, in which to present his ideas to a wider audience and convince those who still doubted the correctness of his vision. He now had the money to hire assistants and to build a laboratory in which to do experimental research. Although most professors bemoaned the impossibility of hiring and keeping good assistants, Birkeland was able to poach the best young men with promises of exciting research and a generous salary. Ole Andreas Krogness and Lars Vegard, both graduates of Birkeland's physics course, were employed to help Sem Sæland process measurements and observations from the Aurora Polaris Expedition.

**Kotzebue, Alaska: banded aurora with a diffuse veil (taken December 28, 1981).** Forrest Baldwin

**Denali State Park, Alaska: auroral arc joins a curtain of light (taken March 10, 1991).** J. Flinn

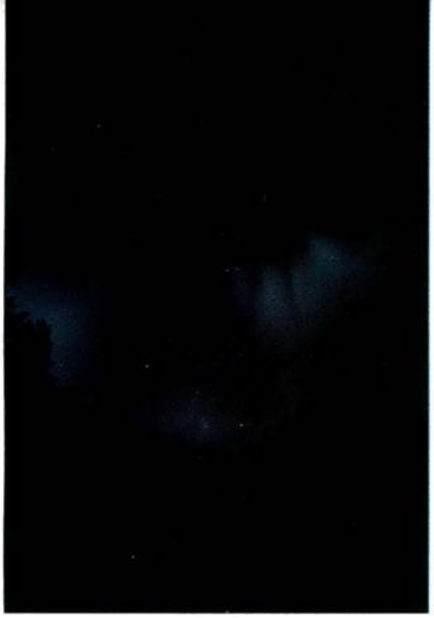
Birkeland wanted his treatise to be a monument in the vast landscape of scientific publications and decided to make it a three-volume work to be published in stages. The first was to be written immediately and would cover the northern lights research and his theories about magnetic storms and currents. His assistants set to work writing descriptions of the Arctic stations, the instruments used, the weather conditions, and the results obtained. Records were collated and processed, maps drawn, and notation systems established. Since the end of the expedition three years earlier, magnetograms had also arrived from 23 observatories across the globe: Honolulu, Bombay, Dehra Dun at the foot of the Himalayas, Baldwin in Kansas, Sitka in Alaska, Cheltenham near Washington, D.C., Christchurch, Toronto, Kew, Stonyhurst, Greenwich, San Fernando in Spain, Wilhelmshaven, Munich, Potsdarn, Pola on the Istrian Peninsula, Pavlovsk, Tiflis, Ekaterinburg, Irkutsk, Batavia on Java, Zi-ka-wei in China, and Val Joyeux near Paris. As Birkeland wrote in the resulting book, "Our observational material of magnetic storms was, I may safely say, the largest that has ever been dealt with at one time."

Birkeland decided to return to his plan to recreate the northern lights in a laboratory, but at the university he had none of the facilities he required. The university had never needed to build and equip a modern research laboratory since so few students chose to study physics. Of the 250 students admitted each year, only 14 majored in sciences and those were divided among geology, botany, mathematics, zoology, astronomy, mineralogy, chemistry, and physics. With his usual lack of regard for convention, he wrote to the administration of the university, informing them that he would need to convert the basement below his room to hold a generator. He also notified them that "I have taken half of the lecture hall for a new laboratory. By putting the students closer together, there is enough space in the reduced hall."

A testy reply granted him permission to use the room but stressed that all alterations and equipment must be provided at his own expense. Telegrams were dispatched to the best scientific equipment manufacturers in Europe and Russia with requests for catalogues and prices, technical performances, and speed of delivery.

Within weeks, the first of Birkeland's purchases began to arrive in the university courtyard, including a 15,000-watt Swiss-built generator that delivered a voltage as high as 20,000 volts and provided a loud background hum to the law lectures given nearby. Boxes marked "fragile" and "heavy" appeared in his office, and, like a child at Christmas, Birkeland rushed to discover their contents. Over the course of a few weeks the bare concrete shell of the basement was festooned with wires, fuse boxes, tool racks, wooden plinths, camera tripods, buzzing and sparking machines, vacuum flasks, electric cables, plugs, batteries, buckets of pitch, and brushes. It soon became apparent that the room was too small for Birkeland's extraordinary plans and the lecture hall too distant to be practical. The only solution was to put some of the equipment in his office, linking it with the basement below by boring small holes in the floor through which to pass electric cables. Birkeland asked the administration for yet another room to use as an office. Meanwhile, a third science graduate, Olaf Devik, was hired to help Birkeland and Dietrichson with the experiments.

To the casual visitor, the laboratory appeared to be the work of medieval visionaries with futuristic dreams. The noises, flashes, smells, and heat were overwhelming and lurking within were a number of very real dangers. The vacuum pumps released poisonous mercury fumes; the small amount of radium salt that had been given to Birkeland by Marie Curie was left on a shelf beside a box of new light bulbs, leaking lethal radiation; explosions and implosions from the vacuum flasks were an ever-present risk; the generator had moving parts that could slice off fingers. Everyone working there suffered frequent electric shocks of varying severity caused by experimental, hurried wiring and the occasionally capricious behavior of electric currents and equipment. Birkeland and his assistants adopted the practice of working with one hand in their pockets so that, if they sustained a large electric shock, it would travel down their bodies rather than across their hearts. Birkeland's own safety precautions caused some comment among his assistants and colleagues. On arriving in the morning, he would replace his hat with an Egyptian fez and put on a pair of red leather Egyptian slippers with long, pointed tips. To those who asked the



**Lancaster, Ontario, Canada: dark coronal aurora with slight veil (taken November 9, 1991).** George Lividaras

**Sapello, New Mexico: sky-wide diffuse curtain aurora (taken November 9, 1991).** Gary A. Becker

reason for his fanciful attire, he explained that he suffered from frequent headaches due to the harmful rays emitted by his experiments and that the fez protected his head. Although it was true that he suffered from headaches, he was perfectly aware that a small felt hat would not stop radiation and he told the tale merely to see who was gullible enough to believe it. As for the slippers, it was simply to avoid wearing wet boots in the laboratory.

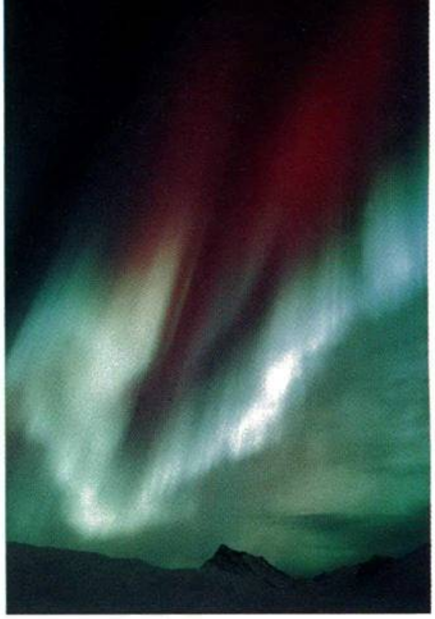
Birkeland's Egyptian accessories were more than just a joke, though. Egyptology had been fashionable throughout the West in his youth due to the enthralling excavations in the pyramids and Valley of the Kings. His isolated boyhood had been punctuated by Professor Lieblein's Sunday lectures about ancient Egypt. Lieblein's son, Johan, was one year older than Birkeland and the two were friends. Birkeland used to go to the professor's house, where he listened to stories about the excavations in Luxor and at the pyramids at Giza, heard about the glories of the pharaohs and the worship of Ra, the sun god. Lieblein, together with Ibsen, had represented Norway at the opening of the Suez Canal in 1869 and he had described how they had sailed up the Nile to the cataracts, as the guests of Khedive Ismail, Egypt's ruler.

The sun was the celestial body that held the greatest fascination for Birkeland. When his interest in physics developed, he realized that Egypt was also the land of a strange phenomenon as mysterious as the aurora borealis. The zodiacal light appeared in equatorial skies after sunset and was sometimes considered the natural explanation behind Moses's "Pillar of Fire" because it was shaped like an elongated pyramid of glowing light stretching from the horizon into space. It was another of Earth's mysteries that taunted the scientists who traveled to study it, and Birkeland hoped that one day he would experience for himself this mystical phenomenon. Until then, his fez and his slippers were a reminder that the sun's influence stretched around the globe, from the flickering lights of the Arctic to the glowing columns in the night skies of Arabia.

The instruments for recreating the northern lights did not exist beyond Birkeland's dreams and drawings, so he and Dietrichson set about constructing them themselves. Initially they used Crookes's tubes, glass cylinders first made in the 1850s, for experiments where a vacuum was needed. At one end of the tube was a cathode, a negatively charged electrode that emitted a beam of high-velocity electrons or "cathode rays" when heated; at the other was an anode to receive the rays. In Birkeland's experiments the anode was given the form of a small, magnetized metal globe, representing the Earth. He called it a terrella, after William Gilbert. Birkeland found it immensely satisfying to be performing his experiments almost exactly 300 years after Gilbert first published his thesis on the Earth's magnetism. The terrellas Gilbert used were naturally magnetic lodestones, whereas Birkeland was able to magnetize his globes artificially by fitting them with an electromagnet consisting of an iron core wound round with copper wire insulated with silk. The ball itself was made from a thin sheet of brass covered with a coat of barium platinocide that was phosphorescent and would glow when hit by flying electrons. The magnet was slightly off vertical to imitate the tilt of the Earth's poles. When Birkeland turned on the cathode, the electrons would stream into the vacuum in all directions until he turned on the magnet in the globe. Once magnetized, the electrons were guided to the poles of the Earth along the magnetic field lines, creating glowing ovals around them, just as Birkeland suspected: auroral ovals formed around the poles of the planet.

When Birkeland tried to perform these experiments on a larger scale, the tubes either shattered at the crucial moment or the curved glass of the cylinder distorted the view of the phenomena occurring inside. He searched in vain for a vacuum chamber that would avoid these problems until, after several months of inquiries, a tube arrived that satisfied most of his requirements. It was almost the size of a man's torso, oblong with curved corners and sides as straight as it was possible to make. On the morning of the first test of this large terrella, Birkeland arrived at his office early. Standing outside, he could hear the regular breathing of the vacuum pump and the distant grind of the generator. He had slept little the night before, not because of nerves but because of excitement. Birkeland donned his Egyptian fez and slippers and then sat down to do some calculations before his assistants arrived. By ten o'clock the laboratory was buzzing with excited conversation: Birkeland and his assistants had been

**White Pass, near the Alaska/Canada border: diffuse curtain aurora (taken February 11, 2000).** Michael Klensch



**Tutshi Lake, British Columbia, Canada: banded curtain with diffuse rays (taken February 5, 2001).** Michael Klensch

joined by professors and students who had heard via the grapevine that Birkeland was to make his own northern lights that day, in his own miniature universe. Amund Helland was there, laughing loudly at Karl's retelling of Birkeland's practical joke of shutting him into the vacuum chamber one day while he was cleaning it. Birkeland loved playing jokes on his assistants. He had once strongly magnetized a metal bar and then casually asked Devik to move it. It was impossible to budge. After a while the other assistants joined Devik and struggled to move it a few centimeters. Just as they were all heaving on the bar as hard as they could, Birkeland switched off the power to the magnet and the bar went flying off the metal table and his assistants flew with it. On this day, however, Birkeland was too preoccupied to think of playing games.

With his usual flair, Birkeland explained to his impromptu audience — which by now also included the director of the Christiania Observatory as well as several professors of math, geology, and law, the latter wanting to see the fruits of the process that had been disturbing their lectures for months — the principles behind the vacuum chamber, how it represented the Earth and would show, for the first time ever, how our world reacts to unknown forces in space. The room was crackling with anticipation as Birkeland closed the shutters of the three large windows, orchestrating his own sundown. The noise of the generator increased and the audience had to shout its questions and observations. After a little while the tip of the cathode, "the sun," began to glow hot. Still "the Earth" lay in darkness. Once Birkeland was satisfied that electrons were streaming from the cathode, he flicked the switch beside the chamber and powered the electromagnet in the terrella. Within seconds, a purple glow could be seen encircling the Earth at the equator. As Birkeland increased the strength of the magnetic field around the Earth, the circle divided, and two circles began to move toward the poles. The audience fell silent as the two spiral rings of glowing, phosphorescent light hovered around the poles of the Earth, eerie and magical. The miniature aurorae were the most supernatural phenomenon the men in that room had ever seen, and yet it was a scientific experiment, aiming to provide explanations and boundaries to an occurrence that had always defied definition. Even the least fanciful of those gathered around Birkeland's terrella had a fleeting moment of awe, looking at the Earth as if from space. Only Birkeland had any idea of how aurorae could be conjured out of nothing, could glow with such lively intensity, could find their way to the poles of the Earth, could be so beautiful. After a few minutes Birkeland turned off the magnet and the cathode in the terrella; the glow disappeared, and the audience took a collective breath. He opened the shutters and laughed at the stunned faces of his visitors. He could not have hoped for more. With this experiment, he was going to make his doubting detractors sit up and acknowledge the value of his theories.

When the first volume of Birkeland's book was published in early 1908, it was a triumph of completeness, handsome in its gold-embossed calfskin binding. Published in English and distributed by Scandinavian, German, British, and French presses, *The Norwegian Aurora Polaris Expedition, 1902–1903,* assumed landmark status. This monumental achievement, made more remarkable by the fact that Birkeland had needed to earn most of the money to make it possible, cemented Norway's position in the international scientific arena and encouraged those who were trying to progress beyond the limited vision of the previous generation of Norwegian academics.

The book opened with personal accounts of Birkeland's adventures in Finnmark, his battles with the weather, descriptions of the local Sami, Hætta the postman, and assorted curiosities to intrigue the reader. He then described the Arctic stations from his second expedition, again emphasizing the tremendous obstacles faced by the pioneering researchers because of the weather and the remoteness of the locations. Encounters with whalers, hunting trips, meetings with Samoyed families, and photographs of the fur-clad explorer-scientists were included to give the work the aura and mystique of polar pioneering. The magnetic recordings from the field studies and from stations around the world were analyzed and compared with the experiments Birkeland had been making with the large Crookes vacuum tubes and terrellas. A few photographs of the small globes with artificial auroral ovals around the poles were included to great

**Kotzebue, Alaska: tight arc adjacent to a banded curtain aurora (taken March 29, 1982).** Forrest Baldwin

**Saint Nérée, Quebec, Canada: banded corona with diffuse rays and arcs (taken August 12, 2000).** Daniel Tardif

effect. Long tables of equations, magnetic recordings, hundreds of maps of the world bristling with arrows showing the direction of the magnetic storms across the surface of the planet, diagrams of current systems and copies of actual magnetograms were also included. It was a paradigm of scientific craftsmanship and research.

The book's conclusions were no less extraordinary. From the recordings around the globe, Birkeland divided all known storm patterns into three categories, one of which, the "polar elementary storm," was his own discovery. Birkeland had suspected this form of magnetic disturbance was responsible for creating the aurorae during his first trip to Haldde, but did not mention it in the resulting book because he lacked proof. His single Arctic station was too limited to reveal magnetic changes across the region, and most other magnetic observatories were in the midlatitudes and did not pick up evidence of polar perturbations. Establishing four stations during the second expedition had provided the evidence he needed to describe this new category of magnetic disturbance and its relationship to the aurorae. Through his study of these well-defined and quite local storms, Birkeland was able to deduce, from his knowledge of electromagnetism, that the energy powering these storms and the northern lights had to originate outside the Earth, in space, ultimately from the sun.

This was the most controversial element in his book, as many scientists refused to believe that the sun could be the origin of cathode rays that reached as far as the Earth. Their main objection was that if only electrons, negatively charged rays, were emitted, the sun would eventually become positively charged and also that the repulsive electric forces between electrons would quickly disperse the beams. Birkeland, however, knew that corpuscles of both charges escaped from the sun but deduced, accurately, that mainly negatively charged electrons caused magnetic storms and aurorae.

"From a physical point of view it is most probable that solar rays are neither exclusively negative nor positive rays, but of both kinds . . . if any positive rays do penetrate into the Earth's atmosphere, they have hardly any perceptible magnetic effect."

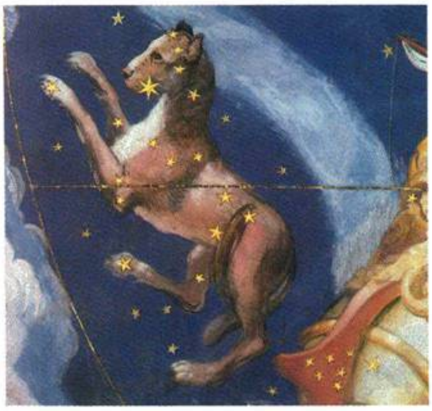
In this way, by using the terrellas in conjunction with magnetic results, Birkeland had surmised the existence of a continuous outpouring of equal numbers of positively and negatively charged particles from the sun. He knew that the sun must continuously emit charged particles and suggested that the cathode rays that caused aurorae were forced into space from the areas around sunspots, and that some were responsible for magnetic storms around Earth.

Birkeland believed that the electromagnetic influence of the sun on near and distant space was as important as that of gravity. He took the laws of electric and magnetic forces, first written in Maxwell's equations, and applied them to space. Before Newton, it was believed that terrestrial mechanics and celestial mechanics obeyed different laws, but Newton showed that a falling apple on Earth moved according to the same laws as it would on the moon — a great breakthrough in physics and particularly in mechanics. Although later scientists revealed limitations in Newtonian law, Birkeland was the first to stress the importance of electromagnetic effects in cosmic physics.

Copies of Birkeland's 300-page book were sent to the great scientists of Europe, to crowned heads of state, to Wallenberg and Eyde. He received acknowledgments from King Edward, King Haakon, King Oscar, and Kaiser Wilhelm, as well as from Henri Poincaré, Sir William Crookes, and many other scientists. In France his work was read with interest, but elsewhere, particularly in Britain, it was largely ignored, and the few reviews it received were negative. Arthur Schuster, Fellow of the Royal Society and a prominent scientist in the field of terrestrial magnetism, said Birkeland had stepped too far out of line. Schuster condemned Birkeland's theories for assuming that only negative rays were emitted by the sun. Had he read more carefully, or with a more open mind, Schuster would have realized that Birkeland knew that both positive and negative particles were thrown out, but had deduced that only negative ones caused aurorae. However, Schuster dismissed Birkeland's huge volume with a terse comment in the Society's Proceedings:

"Even originally well-defined pencils of cathode rays from the sun cannot reach the Earth. For Birkeland's theories to be correct, the existence of such cathode rays is clearly presupposed to be necessary . . . and this assumption is untenable." ■

# Canis Major



Artwork from *The Glorious Constellations*, ©1991; Harry N. Abrams, Inc.

*This small constellation packs a pleasing blend of Milky Way treasures and distant galaxies.*

**by Tom Polakis**

Ask most people to describe a perfect winter's evening and you'll hear tales of warm houses and cozy fireplaces. But deep-sky observers are a breed apart. To them, winter evenings conjure thoughts of crystal-clear nights spent gazing at the brilliant star patterns of the winter Milky Way. At this time of year, the familiar constellation Orion dominates the view to the south. If you draw a line through Orion's belt stars and extend it to the southeast, your gaze will ultimately land on the brightest star in the sky — Sirius — the focal point of the constellation Canis Major the Big Dog.

Despite its small size, Canis Major contains 30 stars shining at magnitude 5.0 or brighter. Sirius proves an anomaly among these generally distant stars: At a distance of just 8.6 light-years, it ranks as the seventh closest star to the sun. That's why it appears so bright in our sky. In the grand scheme of things, the Dog Star turns out to be relatively modest, shining with the light of 22 suns. Contrast that with the luminaries that comprise the rest of the dog. Most lie several hundred light-years away and radiate hundreds or thousands of times more light than the sun.

The Milky Way clips the northeastern corner of Canis Major, resulting in a constellation with a split personality — clusters and nebulae dominate one half while galaxies rule the other. **Sirius** (Alpha [α] Canis Majoris) lies near the dividing line and certainly warrants a close look through the telescope. Hunt for the star's famous binary companion, Sirius B, which currently lies 5" to the primary's southeast. Although 5" may sound like a generous separation, only telescopes with superb optics and excellent contrast will show "the Pup." That's because it glows dimly at magnitude 8.5, fully 10,000 times fainter than Sirius. From our vantage point, the orbital motion of Sirius B is carrying that star away from the brilliant primary. The separation will have increased to 7" by 2005, making the pair easier to split.

In many respects, Sirius B turns out to be more interesting than its neighbor. Astronomer Friedrich Bessel got the ball rolling by studying the motion of Sirius across the sky between 1834 and 1844. He noted a wobble and concluded that the star must have an unseen companion revolving around it with a period of 50 years. In 1862, lensmaker Alvan Clark serendipitously discovered the dim neighbor while he was testing a new 18.5-inch optic.

Walter Adams at Mount Wilson Observatory discovered the true and seemingly unbelievable nature of Sirius B in 1915 by taking a spectrum of it. He found that the star was several thousand degrees hotter than the sun and thus radiated much more energy from each square inch of its surface. For it to appear so dim, it had to be tiny. Adams had shown that Sirius B is a white dwarf — a star with the mass of the sun packed into a sphere roughly the size of Earth and thus having a density of about one ton per cubic inch. Even today Sirius B remains among the most massive white dwarfs known.

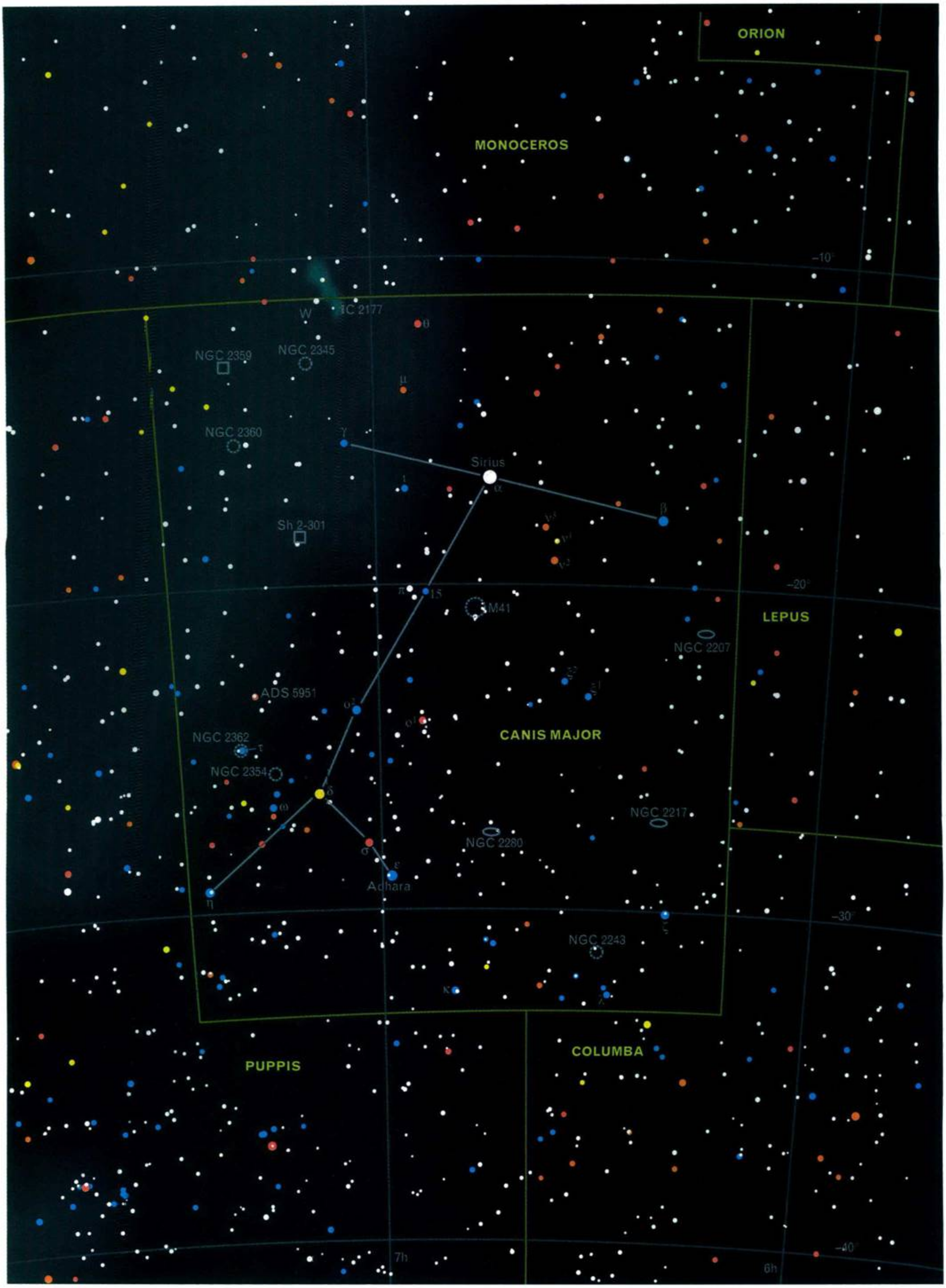
Using Sirius as a starting point, drop 4° due south to locate **M41** (NGC 2287), the sole Messier object in Canis

IC 2177

George Greaney

Major. This big, bright open cluster looks nice through any telescope. At 80x, a scattered but well-defined group of 75 stars fills the field of view. Although most of the stars appear blue or white, the brightest one shows a distinct orange color. This 7th-magnitude gem lies near the center of the cluster. The rest of the cluster members span a wide range of brightness, with at least a dozen stars brighter than 9th magnitude and 60 stars going down to 11th magnitude. M41 lies about 2,000 light-years from Earth and measures 20 light-years across.

From 2nd-magnitude Beta (β) Canis Majoris, pan 4° south-southwest to **NGC 2207**, a spiral galaxy interacting with its neighbor, IC 2163. Astronomers think that the two spirals collided roughly 40 million years ago. On long-exposure photographs, the spiral form of the two galaxies appears distorted. In a 10-inch telescope, NGC 2207 shows a bright core surrounded by a small, moderately faint halo elongated east-west. A 13th-magnitude foreground star appears embedded in the northwestern edge. IC 2163 lies to the east of its partner and shows a faint,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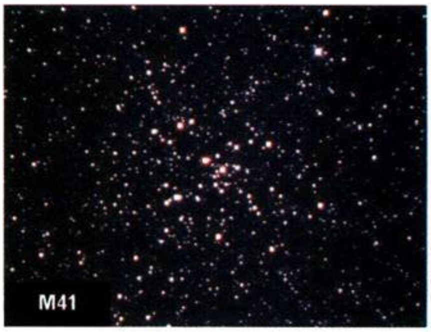
broadly concentrated glow measuring 2' across. The field is richly studded with Milky Way stars. The light you see from these galaxies has traveled for 130 million years to reach us.

Next hop 3° north of 3rd-magnitude Zeta (ζ) Canis Majoris to find the barred spiral galaxy **NGC 2217**. Through a large telescope, you'll see a diffuse, uniform haze some 3' across surrounding a brighter core. Careful observers may notice a slight elongation to the outer halo.

Our next stop lies in a sparse star field in the southern reaches of Canis Major, near the border with Columba. **NGC 2243** ranks among the older open clusters — having formed about 4 billion years ago — and does a good impersonation of a globular cluster. An 8-inch telescope reveals a dozen or so faint stars against a hazy glow that spans 3'. A 16-inch scope reveals 30 stars, but the object continues to resemble a distant globular. (Not surprising, considering that NGC 2243 resides 13,000 light-years from Earth.) Use the highest magnification to see how many stars your scope will resolve.

Sweep 5° northeast of NGC 2243 and you'll land on **NGC 2280**, a rather modest galaxy that's more interesting for the surrounding star pattern. In a 12-inch telescope, the galaxy appears as a moderately bright mist measuring 2' by 1' with a broadly concentrated center. You'll know you've located it if you identify an asterism that looks curiously similar to the bowl of the Big Dipper.


M41

Lee C. Coombs

NGC 2207

David Healy

Our next group of objects lies in eastern Canis Major, just north of the Big Dog's tail. First find 2nd-magnitude Delta (δ) Canis Majoris and then scan at low magnification 1.5° to the east-northeast. You should sweep up the large, scattered open cluster **NGC 2354**. A handful of 9th- and 10th-magnitude stars join with 60 fainter cluster members in a field that teams with Milky Way stars. A ring of the cluster's brighter stars seems to create a central starless void.

The 4th-magnitude star Tau (τ) Canis Majoris forms the centerpiece of our next open cluster, **NGC 2362**. This is no chance alignment. The highly luminous star sits in a cluster that lies 5,000 light-years away and whose next brightest member glows a full 3 magnitudes fainter. It makes for a stunning sight in any telescope. A tight group of 10th-magnitude stars spanning just 6' surrounds Tau, which floods the view with its brilliant light. Look for two bluish companions just to the east of Tau. Some references indicate that a nebula surrounds NGC 2362, but this is almost certainly an artifact of haze that seems to emanate from the brilliant central member.

Less than 2° north-northwest of NGC 2362 lies **ADS 5951**, a gorgeous double star that some observers have dubbed "the Winter Albireo" because of its color contrast. Some of the perceived color may be psychological, however. The 5th-magnitude primary star certainly glows with an orange hue, but the 7th-magnitude secondary, easily resolved some 27" to the north-

## Deep-Sky Objects in Canis Major

| Object | R. A. (2000.0) | Dec. | Mag. | Size/Sep. | Type | Notes |
|---|---|---|---|---|---|---|
| NGC 2207 | 6h16.4m | –21°22' | 10.8 | 4.8' by 2.3' | Gal | SAB(r)c |
| NGC 2217 | 6h21.7m | –27°14' | 10.2 | 5.0' by 4.5' | Gal | (R)SB(r)0 |
| NGC 2243 | 6h29.8m | –31°17' | 9.4 | 13' | OC | |
| NGC 2280 | 6h44.8m | –27°38' | 10.5 | 6.3' by 2.8' | Gal | SA(s)c |
| Sirius | 6h45.1m | –16°43' | –1.5/8.5 | 5.0" | Dbl | |
| M41 (NGC 2287) | 6h47.0m | –20°44' | 4.5 | 38' | OC | |
| IC 2177 | 7h05.3m | –10°38' | — | 120' by 40' | BN | Seagull Nebula |
| W Canis Majoris | 7h08.1m | –11°55' | 6.6 | — | Star | Carbon star |
| NGC 2345 | 7h08.3m | –13°10' | 7.7 | 12' | OC | |
| Sharpless 2-301 | 7h09.8m | –18°29' | — | 8' by 7' | BN | |
| NGC 2354 | 7h14.3m | –25°44' | 6.5 | 20' | OC | |
| ADS 5951 | 7h16.6m | –23°19' | 4.8/6.8 | 26.8" | Dbl | |
| NGC 2360 | 7h17.8m | –15°37' | 7.2 | 12' | OC | |
| NGC 2359 | 7h18.6m | –13°12' | — | 9' by 6' | BN | Duck Nebula |
| NGC 2362 | 7h18.8m | –24°57' | 4.1 | 8' | OC | |

**Object:** Designation in Messier, NGC, or other catalog. **R.A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep.:** Size in arcminutes; separation in arcseconds. **Notes:** Hubble type for galaxies.

## The Big Dog

> *"The great Overdog, That heavenly beast, With a star in one eye, Gives a leap in the east./He dances upright, All the way to the west, And never once drops, On his forefeet to rest./I'm a poor underdog, But to-night I will bark, With the great Overdog, That romps through the dark."*
> Canis Major, *Robert Frost (1874–1963)*

Few hunters feel complete without a trusty canine companion, and that certainly held true for the greatest hunter of all. Orion's earthly tenure was aided by a pair of faithful dogs — Canis Major and Canis Minor — and it seems only fitting that the two were elevated into the heavens along with their master. There they tag along at the hunter's feet, ever ready to help him chase down Taurus the Bull.

But it shouldn't come as a big surprise that ancient people paid less attention to the constellation Canis Major and more to its brightest star, Sirius. Sirius easily outshines every other star in the night sky, and it lies close enough to the celestial equator that it can be seen from everywhere on Earth outside the polar regions.

The ancient Egyptians revered Sirius because its appearance heralded the rise of the Nile River. Every year, Sirius returned to view in the east just before dawn around the summer solstice. The Nile was soon swollen with water and the agricultural lifeblood of the civilization returned.

The lands on the northern shores of the Mediterranean took a decidedly different view of Sirius. The sun and Sirius lay in the same part of the sky from mid-July through August, and the ancient Greeks and Romans thought that Sirius added just enough heat and light to make late summer uncomfortable. They referred to that hot and sultry period as the "Dog Star Days," which eventually got shortened to dog days. — *Richard Talcott*

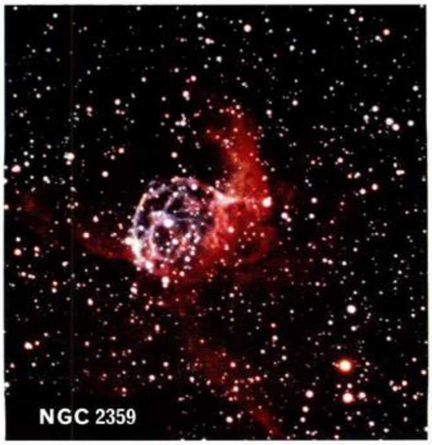
east, appears blue only in contrast. In fact, this rather ordinary white star is no more blue than Sirius. If you use high power to eliminate the primary from the field of view, the secondary indeed appears white. In any event, the pair still makes for a stunning sight.

The diffuse nebula **IC 2177**, the Seagull Nebula, spills over from Canis Major's northern neighbor, Monoceros. A rich-field telescope equipped with a nebula filter brings out a patchy haze measuring 2° long and 0.5° wide. Star chains extend along the length of the nebula. At the southern end of the strip lies the reflection nebula Cederblad 90. Despite the obscure designation, it glows brightly as it reflects the light of the 8th-magnitude star that lies at its center. The nebula measures 3' across and appears round with a hazy edge. It shows up best when viewed without a nebula filter.

Scan a little less than 1° northeast of Cederblad 90 and you'll come to the bright carbon star **W Canis Majoris**. Any telescope will reveal the deep red hue of this 7th-magnitude gem. A small reflection nebula surrounds W Canis Majoris, but its deep red color renders it invisible in backyard instruments.

Now pan 1.2° south to find the open cluster **NGC 2345**. Here you will see about 40 stars, most shining at 12th- or 13th-magnitude, compressed into an area 10' across. Despite the rich surrounding field, the cluster stands out well.

Just 2.5° due east of this cluster lies the highly ionized emission nebula **NGC 2359**, sometimes called the Duck Nebula. This was one of the first three Wolf-Rayet bubbles identified. These large interstellar bubbles form around some Wolf-Rayet stars, a class of hot stars exceptional for their extremely large stellar winds. The nebula we see is material that has been swept up by the winds and not material ejected from the star. The Duck Nebula responds magnificently to nebula filters. At intermediate magnifications, the brightest feature is the duck's bill, a 4' by 1' extension on the nebula's southern end. The bubble itself appears as a slightly fainter network of interlacing filaments that measures 4' across. Large telescopes at high powers provide spectacularly detailed views of NGC 2359.



**NGC 2359**

Ken Blankenship

The pleasing open cluster **NGC 2360** lies 2.4° south of the Duck Nebula. A 10-inch telescope shows 60 stars between 11th and 13th magnitudes in an area 8' across. The star density appears highest on the cluster's western edge, while the eastern half blends gradually with the surrounding star field. A conspicuous 9th-magnitude star sits just off the eastern edge of NGC 2360; a 5th-magnitude field star lies less than half a degree to the west.

We close our tour with the bright emission nebula **Sharpless 2-301**. Located 42,000 light-years from the Milky Way's center, it resides in the outer region of the galaxy that contains few nebulae. An unfiltered 8-inch telescope shows a haze some 5' across with a bright center lying in a rich field, but a nebula filter improves the view markedly. Larger apertures bring out a mottled texture to the bright nebula.

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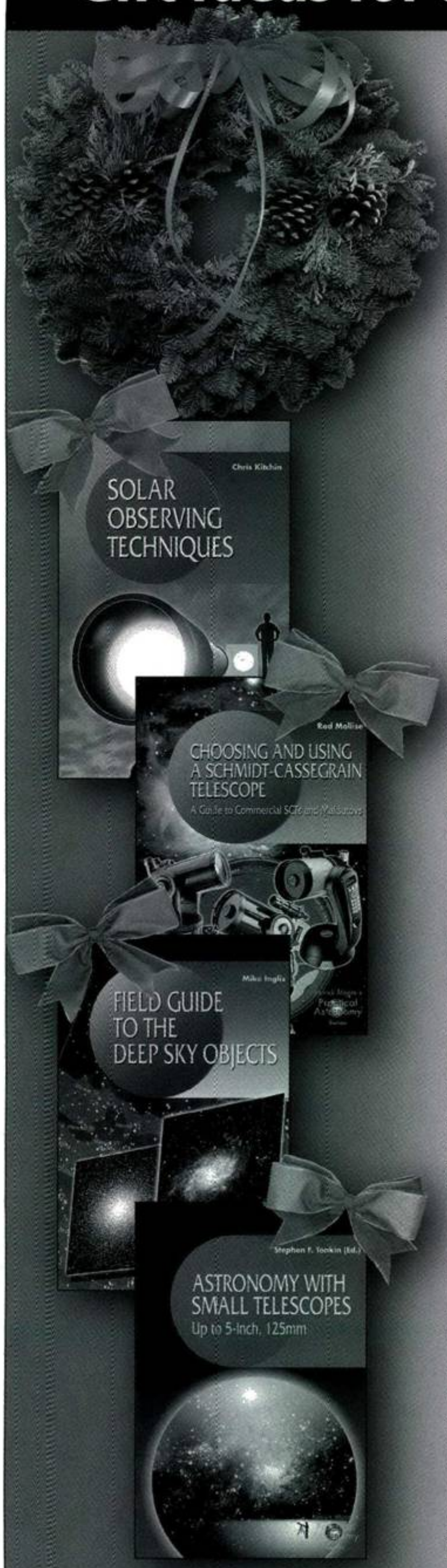
*Tom Polakis is an aerospace engineer living in Tempe, Arizona. His favorite astronomical pursuits are deep-sky observing and photography.*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# Beginner's saturn

1 Saturn, a gaseous sphere, is the second largest planet.

2 Most of what we know about Saturn we learned from the two Voyager missions of the 1970s and early 1980s.

3 Saturn's stratosphere contains carbon dioxide and water.

4 Saturn takes 29.5 years to orbit the sun, but spins once around on its axis in 10 hours and 14 minutes.

5 At last count, Saturn had 30 moons.

6 Astronomers believe that Saturn's dynamic and complex rings hold the clues to the evolutionary processes of the solar system. The majority of the ring particles are composed of water ice and range in size from one centimeter to five meters.

7 The rings are labeled A through G, named in order of their discovery, rather than their placement.

8 Saturn is not the only ringed planet: over the last three decades, astronomers detected rings around Jupiter, Uranus, and Neptune.

9 Saturn's rings appear edge-on to Earth every 14 years. This will happen again in 2009.

10 Saturn and Jupiter both emit more thermal energy to space than they receive from the sun.

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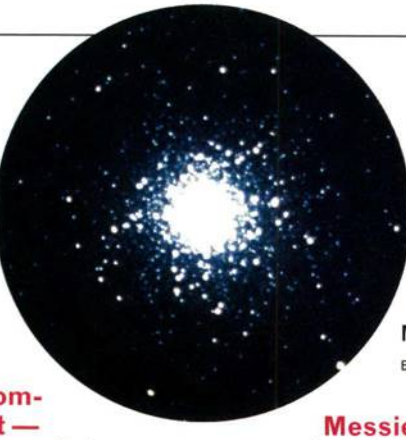
# Glossary



**M13 in Hercules**

Bill Iburg

**Astronomical unit** — the average distance between the sun and Earth, roughly 93 million miles.

**Electromagnetism** — a fundamental physical force that is responsible for interactions between charged particles. It extends over infinite distance.

**Globular cluster** — a densely packed cluster containing millions of stars.

**Light-year** — the distance a ray of light travels in one year; one light-year equals about six trillion miles.

**Messier Catalog** — a catalog of 107 of the brightest galaxies, star clusters, and nebulae, compiled by French astronomer Charles Messier in the 18th century. These objects are identified by an "M" before the number.

**Nebula** — a cloud of interstellar gas and dust, appearing as a bright or dark patch in a star field.

**NGC** — *New General Catalogue,* a numbered collection of 7,840 celestial objects compiled by J. L. E. Dreyer and published in 1888.

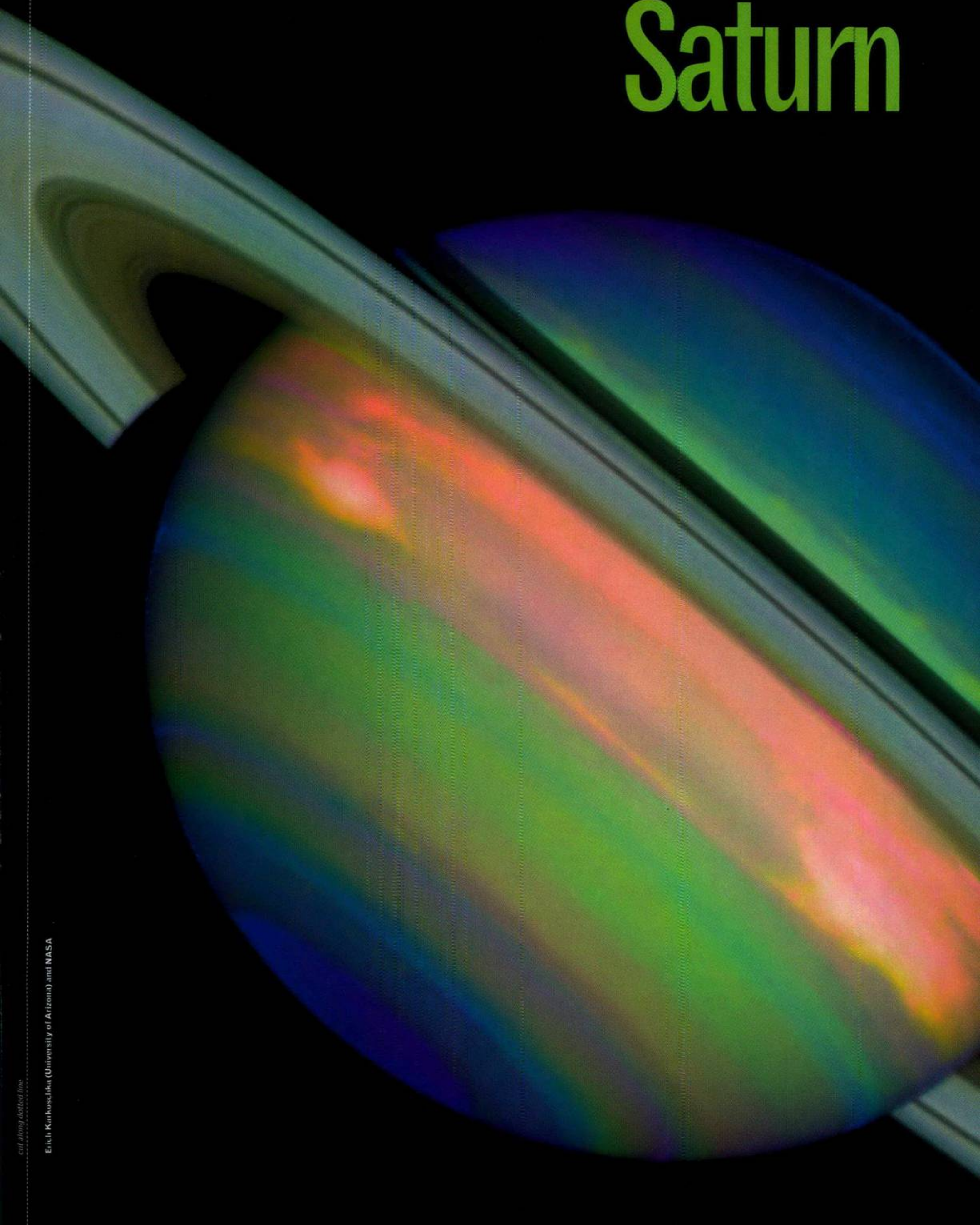
**Planetary nebulae** — not planets at all, but shells of illuminated gas surrounding old, dying stars.

**Solar wind** — a steady, supersonic plasma stream (mainly electrons and protons) moving out from the sun in all directions into space.

**Supernova** — a massive star that catastrophically explodes, releasing so much energy that it can briefly outshine an entire galaxy.

*While you may find some new terms among these entries, many of them appear in articles throughout this issue.*

# Saturn



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Erich Karkoschka (University of Arizona) and NASA

# Beginner's sky

### Diary of a neophyte astronomer. By Jerry Burstein

**"So, why don't we run a column written by a regular sort of guy? You know, someone who's always wanted to learn more but never did. Let's just point him in the right direction, throw some beginner equipment his way, and get him to share his astronomical viewing adventures with readers. Hey, maybe he even has a sidekick …"**

The above is an excerpt from a recent e-mail I sent to *Astronomy*'s staff. As circulation director (and yeah, a wannabe TV sitcom writer), every once in a while I like to throw ideas out there. Who would think the great minds that put this magazine together would take me seriously?

Record all your observing sessions in this handy, spiral-bound log. It features Hubble images interspersed with plenty of space for notes and drawings. *Astronomical Observing Log*, Astrographic Publishing, 112 pages, Smithtown, New York, 2001; ISBN 0-9706334-2-4; hardcover, $17.95. Order toll-free at 888-8-ASTRO-8; e-mail, mail@astrographics.com; website, www.astrographics.com.

Then one day the phone rang: "Jerry — Are you serious about that everyman-beginner-type-person-checking-out-the-skies idea?" All I could say was, "Why, do you like it?" "Matter of fact — we think you'd be perfect to write it," was the answer. (Me and my big mouth.)

But then I remembered the passion for astronomy I see on the faces of the people I work with as well as those I've met at conventions and star parties. They understand the philosophy behind taking time out on a beautiful night to expand one's mind.

Here's my goal: get a closer look, take time to imagine, and learn about what really lies above. I'm hoping to inspire other beginners to do the same.

#### Bringing Home the Binoculars

"Whoa, Dad. Cool. Let me see, let me, let me!"

Score the first point. My seven-going-on-seventeen-year-old daughter is psyched. To be honest, I'm as excited as she is as we unwrap the "binos."

Instructions … well, we decide to read them later. (You understand, right?) It's a beautiful night in the rural Wisconsin countryside: lots of darkness and magnificently clear skies. Unfortunately, lots of mosquitoes, gnats, and other flying things as well.

"Can I try the binoculars?" my sidekick continually shouts. "Sure," I say, handing them to her. "Wait, wait. Look — I can see the TV really close," she yells, focused on the set. I'm impressed at how steady she is with the binoculars as she pans the house and out the windows.

"Let's go outside," I say, snatching the binos. They are much lighter than I expected as I gaze into the southern and western skies, trying to focus on unknown bright objects. I see a "dipper," but honestly I'm not sure which one. A star chart or guide would be handy about now, I realize. So I walk back to the house for the pull-out "Sky Show" section that *Astronomy* publishes every month.

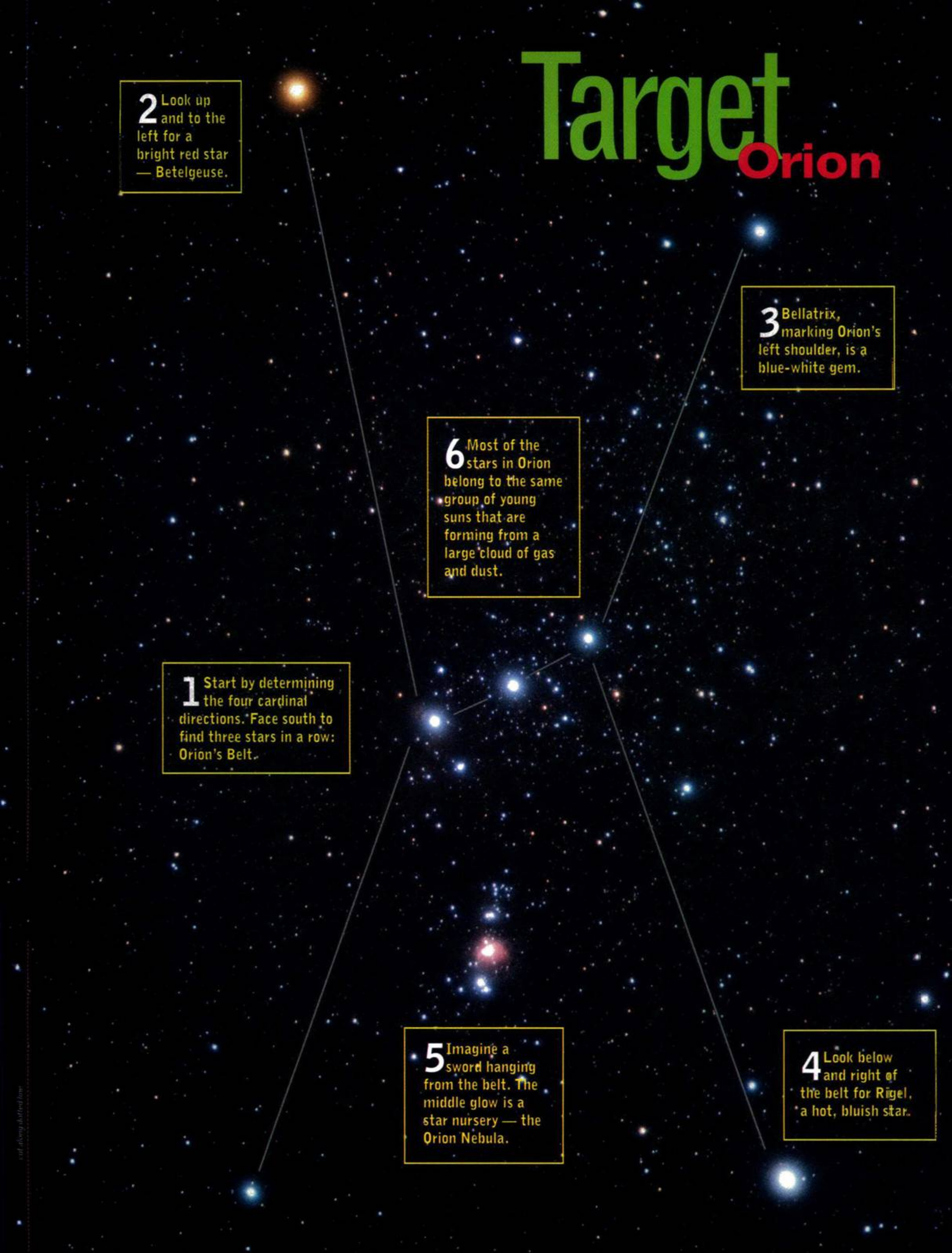
As I'm doing this, my daughter has taken a turn at scanning the skies with the binoculars but is having a problem with the bugs. "I'm going back in," she exclaims. I start to beg her to stay but then think to myself, "Hey, one small step at a time. She seems interested and we've both really enjoyed this little experience. That's a victory right there."

Off she goes. I tuck the "Sky Show" chart under my arm and head back outdoors. "Screw the bugs," I think, and for the next ten minutes or so I alternate between naked-eye stargazing and playing with the binoculars. Can I honestly say I know what I was doing? Probably not, but this was a great start — and my daughter and I agreed later that this was something we want to do more of together.

Want to join us? Then come along for the next several months as I take you on my big adventure. I'll start by learning the sky with and without binoculars. Don't be afraid to offer your suggestions. You can e-mail me at jerry@astronomy.com.

**Target: Orion** — This constellation is probably the easiest naked-eye star group for beginners to identify, perhaps after the Big Dipper. To find Orion, first locate its distinctive belt. From there, you can find other famous names among the stars, as well as Orion's star-jeweled sword. Orion's Sword contains M42, the Orion Nebula, one of the brightest star-forming regions in the sky. Ross Salomone

# Target Orion



**1** Start by determining the four cardinal directions. Face south to find three stars in a row: Orion's Belt.

**2** Look up and to the left for a bright red star — Betelgeuse.

**3** Bellatrix, marking Orion's left shoulder, is a blue-white gem.

**4** Look below and right of the belt for Rigel, a hot, bluish star.

**5** Imagine a sword hanging from the belt. The middle glow is a star nursery — the Orion Nebula.

**6** Most of the stars in Orion belong to the same group of young suns that are forming from a large cloud of gas and dust.

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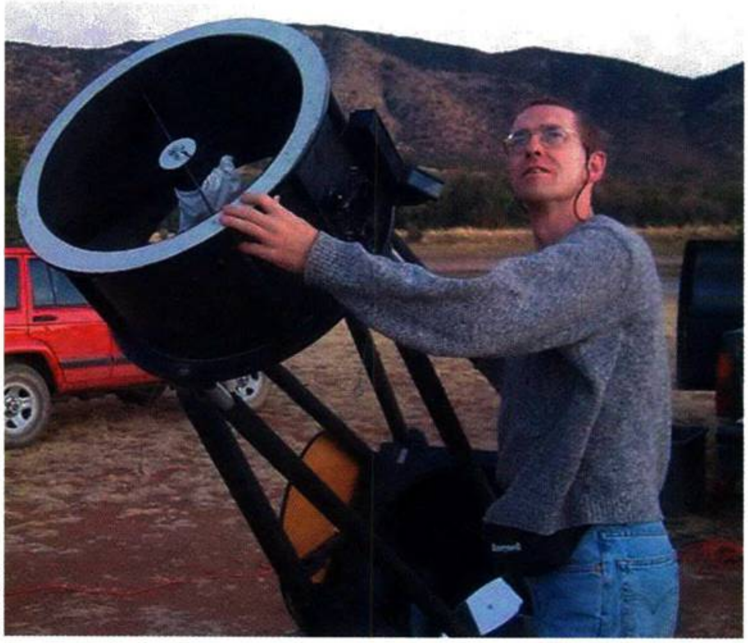
# My Favorite Objects

## Tom Polakis, Tempe, Arizona



Tom Polakis

I came into astronomy as a child of the space program. Only in 1977 did I pick up astronomy in earnest after seeing a display of the Perseid meteors in my home state of Michigan. In 1985 I moved to Arizona to find better skies. Not long after, I began making trips to the Southern Hemisphere to broaden my observing experiences. Starting out, I never could have guessed that astronomy would become such a big part of my life.

### The Veil Nebula

Whenever it's up, I'll always observe it. In my first weeks in Arizona I was treated to a view of this object through a 16-inch scope and the filamentary structure I thought was only visible in photographs. The contrast between the two main rope-like arcs belied the fact that they were from the same supernova remnant. Since then, I have been wowed by this unique object in views with practically every size and type of scope.

### Cluster NGC 7789

For winter observing, I view in comfort from the lowest elevations of western Arizona. I always associate my best views of this magnificent cluster with those sites. NGC 7789 forms a gorgeous array of stars that stands out nicely against an already-starry backdrop. I always notice an illusion of winding, dark lanes that completely elude any photograph.

### Galaxy NGC 891

The sky holds many richly-detailed galaxies, but my favorite one is not one of the brightest. NGC 891 is a great spiral seen exactly along its edge. In my 13-inch scope, I see an evenly-illuminated, ghostly glow separated by a dark lane that reminds me of the Milky Way's brilliant Great Rift. The clincher is the incredibly rich foreground collection of our home galaxy's stars.

### Cluster 47 Tucanae

In 1988 I made my first of five trips to view the sky from the Southern Hemisphere, not knowing that it would become an addiction. From Australia, I saw 47 Tucanae in an 8-inch scope, and it would become my favorite globular cluster. Its competition is Omega Centauri, which is brighter, and has more stars. The two globulars are as different as can be. Unlike Omega Centauri, 47 Tucanae offers as its real attraction a blazing core, which appears more spectacular with each upward step in aperture and magnification.

### The Tarantula Nebula

I never dreamed I would observe from Chile until I was there. It's the best site in the world. Of all the objects I saw, none required less observing skill than the magnificent Tarantula Nebula (NGC 2070).

The tendrils of this emission nebula, the centerpiece of the Large Magellanic Cloud, are plainly visible at first glance. The field is filled with companion star clusters and nebulae, already apparent from an unbelievably large distance.

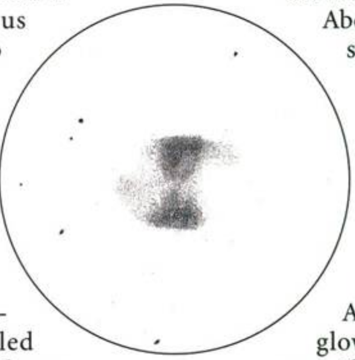
# Strange Days in Perseus

by Richard Jakiel and David Riddle

**The Little Dumbbell Nebula (M76) shows two bright lobes in large scopes.** Jason Ware

Within the richly star-studded borders of Perseus the Hero, a highlight of the winter Milky Way, lies a diverse array of weird nebulae that challenge visual observers. Every major type of nebula is accounted for: emission nebulae, planetary nebulae, dark nebulae, and reflection nebulae. Perseus offers the perfect winter hunting ground to head out and view these objects, but we really encourage you to bring nebula filters along. A good filter can block much of the unwanted light pollution and allow the details of these nebulae to really stand out. Broadband filters like Lumicon's UHC and Deep Sky filters seem to work well at any magnification, while narrow line filters like the O III and Hb filters work best at low to moderate powers. We generally use the O III filter on low surface brightness nebulae, often with dramatic results.

Perhaps the most observed nebula in Perseus is the **Little Dumbbell Nebula** (M76, NGC 650–651). Discovered in 1780 by Pierre Méchain, this object is a large planetary nebula similar in shape to the much larger and brighter Dumbbell Nebula in Vulpecula (M27). William Herschel recorded the apparent duality of this nebula, thus the reason for two NGC numbers. Find the Little Dumbbell by star-hopping your way to Phi (ψ) Persei; then shift your scope about 1° north. With a high surface brightness, the Little Dumbbell is visible in almost any backyard scope. An 8-inch instrument at moderate power reveals a rectangular, nebulous glow subdivided into bright knots. Large backyard scopes with nebula filters can show some of the subtle details often visible in photographs. A 20-incher at 175x with an O III filter uncovers two large, mottled knots surrounded by an oval haze. Low-contrast structures are visible within the haze.

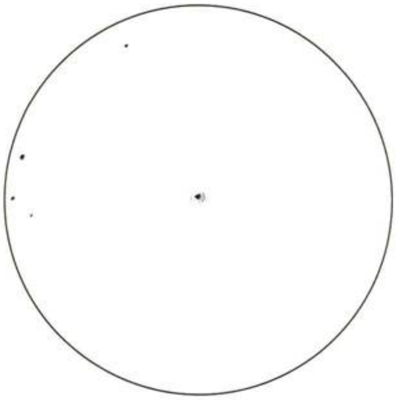


**M76 sketched with a 16-inch scope at 175x with a UHC filter.** Richard Jakiel

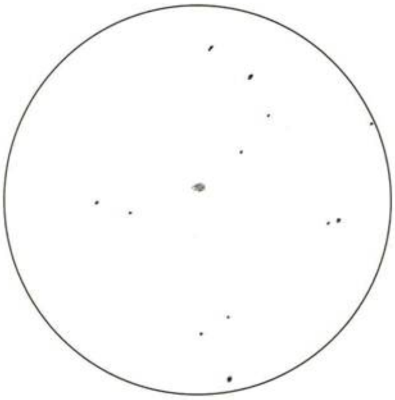
A far more challenging planetary exists in **Abell 4** (PK 144–15.1), located near the splashy open cluster M34. At magnitude 14.4 and 22" in diameter, this object requires a medium-sized scope under dark skies even to spot. Locating Abell 4 with a detailed star atlas such as *Uranometria 2000.0* will be relatively straightforward if you are using a 16-inch or larger scope, as it lies 45' west of M34's core. In the 20-incher, Abell 4 is a dim, faint glow; moderately high magnifications, along with the O III filter, show it as a small, round disk with a fairly bright middle and diffuse edges.

Not all nebulae respond well to filters. Some, like **NGC 1333**, shine

**The odd reflection nebula NGC 1333 offers a dusty treat.** Chuck Vaughn



**IC 351 sketched with a 20-inch scope at 265x using a UHC filter.** Richard Jakiel



**IC 2003 sketched with a 20-inch scope at 265x using a UHC filter.** Richard Jakiel

**The California Nebula, kingpin of the Perseus group.** Gerald Rheman and Franz Kersche

by light reflected from nearby stars and not by ionized gases like those in a fluorescent light. Reflection nebulae require dark skies and clean optics for best visibility. Rich-field scopes at low powers often work best. To find NGC 1333, shift about 2.5° west-southwest from the bright star Omicron (ο) Persei. In an 8-inch scope you'll see a wisp of fairly bright nebulosity just south of a 9th-magnitude star; the nebula's southern edge will be the brightest. While in this locale, also check out **IC 348**, a faint reflection nebula, which lies adjacent to the strange dark nebulae **Barnard 3** and **Barnard 4**. On long-exposure photos IC 348 is quite large, but through a scope only the portion south of Omicron Persei appears to be nebulous.

The area of the lower right "foot" of Perseus holds some other treasures. Two small, bright planetary nebulae, **IC 351** and **IC 2003**, can be found near the bright stars Zeta (ζ), Xi (ξ), and 40 Persei. Easiest to find is IC 2003, as it lies about halfway between Zeta and Xi. About 6" across and glowing at magnitude 11.5, IC 2003 appears in an 8-inch scope as a small, blue-green disk that is star-like at low powers. Under high magnification, the nebula looks slightly oval and unevenly lit.

IC 351 lies slightly west of the midpoint between Xi and 40 Persei. Glowing faintly at 12th magnitude and spanning 8" by 6", IC 351 is a high-surface-brightness nebula sim-

## Spotlight on the Whirlpool Star Party

### Revival on the Emerald Isle

On a moonless night in September 2001, a dream was coming true. Astronomers from far and wide had traveled to Birr, Ireland, hoping that the fickle Irish weather would allow them to do something that hadn't been done for nearly 100 years — to look through the newly-restored Great Telescope of Parsonstown.

In 1845, the massive telescope saw first light as William Parsons, Third Earl of Rosse, confirmed its potential on the double star Castor. The scope was then the largest in the world, and he hoped to use it to confirm his suspicion that nebular clouds visible in smaller scopes contained stars. He succeeded in doing that and more; the Earl's observations laid the foundation for a line of studies that culminated in Edwin Hubble's discovery of the nature of galaxies.

In the early years of the 20th century, the 72-inch Leviathan was last used to measure heat reflected by the moon. It then sank into disrepair, its original wooden tube gently and remorselessly dissolving into seeminbly irreversible oblivion. In recent years, however, Brendan Parsons, 7th Earl of Rosse, the present incumbent of Birr Castle, has taken action. The telescope's restoration was completed nominally in 1998, but further testing problems delayed the telescope's second new light until three years later.

**The base of William Parsons's famous 72-inch Leviathan looms over Whirlpool Star Party attendees.** David Bell

On this September evening in 2001, the telescope's hidden motors slewed the instrument into the rich starfields of Cygnus. The Great Telescope of Parsonstown was back on duty. Ireland's astronomical heritage had once again come alive, and all who were there were awestruck. — *David Bell*

## Challenging Comets/ Jan. 2002

In any month, usually several comets glow brightly enough to become visible to those with large telescopes. Here are coordinates and magnitudes:

**19P/Borrelly**

| | |
|---|---|
| Jan. 1 | 12h38.1m, 39°50', 11.5 |
| Jan. 11 | 12h50.3m, 42°26', 11.9 |
| Jan. 21 | 12h57.3m, 45°09', 12.3 |
| Jan. 31 | 12h58.7m, 47°48', 12.8 |

**C/2000 SV74 (LINEAR)**

| | |
|---|---|
| Jan. 1 | 22h59.4m, 54°34', 13.9 |
| Jan. 11 | 23h00.0m, 54°17', 13.9 |
| Jan. 21 | 23h03.0m, 54°20', 13.9 |
| Jan. 31 | 23h08.0m, 54°44', 14.0 |

**P/2001 Q2 (Petriew)**

| | |
|---|---|
| Jan. 1 | 10h41.2m, –13°53', 14.1 |
| Jan. 11 | 10h35.3m, –14°17', 14.3 |
| Jan. 21 | 10h25.8m, –14°03', 14.5 |
| Jan. 31 | 10h13.8m, –13°07', 14.7 |

**C/1999 Y1 (LINEAR)**

| | |
|---|---|
| Jan. 1 | 21h22.7m, –50°17', 15.0 |
| Jan. 11 | 21h27.8m, –50°03', 15.1 |
| Jan. 21 | 21h33.6m, –49°57', 15.2 |
| Jan. 31 | 21h39.9m, –50°00', 15.3 |

**C/2001 A2 (LINEAR)**

| | |
|---|---|
| Jan. 1 | 21h39.2m, 14°15', 15.3 |
| Jan. 11 | 21h50.4m, 15°00', 15.5 |
| Jan. 21 | 22h01.5m, 15°52', 15.8 |
| Jan. 31 | 22h12.3m, 16°51', 16.0 |

**C/1999 T1 (McNaught-Hartley)**

| | |
|---|---|
| Jan. 1 | 19h39.0m, 43°22', 15.5 |
| Jan. 11 | 19h52.4m, 43°14', 15.6 |
| Jan. 21 | 20h05.2m, 43°18', 15.8 |
| Jan. 31 | 20h17.5m, 43°33', 15.9 |

**7P/Pons-Winnecke**

| | |
|---|---|
| Jan. 1 | 14h21.0m, 8°41', 16.0 |
| Jan. 11 | 14h44.5m, 7°41', 15.5 |
| Jan. 21 | 15h08.9m, 6°46', 15.1 |
| Jan. 31 | 15h34.5m, 5°56', 14.6 |

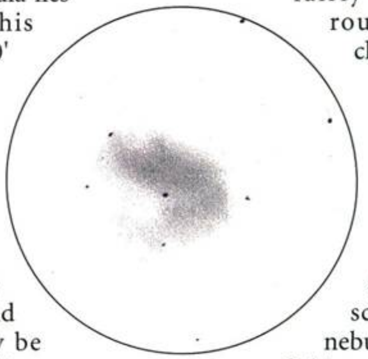
ilar to IC 2003. An 8-inch scope at medium power shows the nebula well. A 20-inch scope operating at 265x and 341x reveals a faint central star set against the nebula's bright core. When looking for such a faint central star, take the nebula filter out of the system, as it will dim the star significantly.

By far the best known and photographed object in the area is the **California Nebula** (NGC 1499), part of the complex of young, hot stars known as the Perseus II Association. High-energy radiation from the bright star Xi Persei excite the gases of the California Nebula into glowing. Xi also makes a convenient guide star, as the nebula lies less than ½° north of the star. The California Nebula spans more than 3° east-west and is nearly 1° wide. Its huge size, coupled with low surface brightness, makes it a challenge for any telescope.

Filters help immensely with seeing the California Nebula. A low-power eyepiece fitted with a narrow band filter works best. Of all the filters we tested, the best on this object was the Hβ, a specialty filter often used to spot the Horsehead Nebula in Orion. A 3-inch or 4-inch wide-field scope with the Hb filter shows outlines of the nebula. Initially, it appears much like the Veil Nebula in Cygnus as viewed with an O III filter. In a larger scope many of the faint details can be glimpsed, including some of the nebula's east-west streaks. Take your time as you scan across the surface of this dim giant. You'll be surprised at how much there is to see.

The unusual reflection nebula **NGC 1579** stands isolated along the Perseus-Auriga border. To find it, star-hop eastward from Xi Persei to a short chain of three 6th-magnitude stars. The nebula lies 2° northeast of this chain and about 10' east of a 7th-magnitude star. Small scopes reveal a diffuse, oval core with faint extensions. In large scopes, faint filamentary structures on the southern and western sides may be visible under dark skies.

**Weird nebula NGC 1579 is a reflection region loaded with dust.** Preston Scott Justis



**NGC 1491 sketched with a 20-inch scope at 165x using a UHC filter.** Richard Jakiel

The last two weird Perseus nebulae lie in the northeastern corner of the constellation. **NGC 1491** is a small, bright emission nebula 1¼° north-northwest of the bright star Lambda (λ) Persei. An 8-inch scope shows an irregular, diffuse glow. A 20-incher reveals wispy filaments and a dark rift that juts in front of a portion of the nebula. Next, shift your scope to the nebulous cluster **NGC 1624**. Begin at Lambda Persei and follow a roughly east-west line of 6th- to 8th-magnitude stars until you reach a 6th-magnitude star close to the Perseus-Auriga border. From there, move ½° northwest. Under dark skies, you will see a fairly bright glow surrounding a compact cluster of stars.

Today's amateur astronomers have access to equipment that would have been the envy of professionals a few generations ago. Large aperture scopes, narrow-band nebula filters, superwide field eyepieces, and detailed star atlases make hunting for objects like unusual nebulae in Perseus a luxurious pastime. Try using *Uranometria 2000.0* as your guide. The challenge is to do it on the best possible nights and to have patience — to see features you can eke out from these residents of the galaxy. ■

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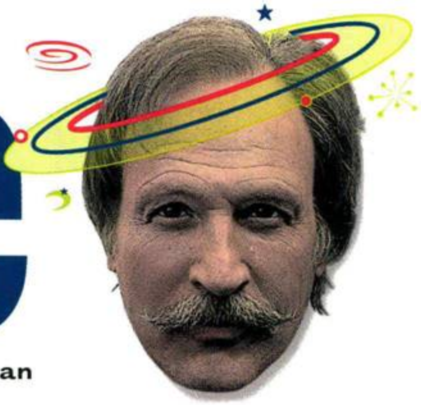
*Richard Jakiel and David Riddle are die-hard deep-sky observers living in the Atlanta area.*

# strange Universe



by Bob Berman

## New Year's Resolution

One New Year's resolution astronomers can't ignore is to resolve fine planetary detail. This year, for the only time in our lives, Jupiter's closest and brightest appearance of the entire year happens during the very first hours of January 1.

This means the largest planet will be the brightest "star" in the midnight heavens on New Year's Eve, reaching its highest position due south just as the clock strikes midnight. This should suggest an auspicious start to the year, and as a bonus, Saturn will be floating high up at very nearly its biggest and brightest as well.

Given a little mathematical quirk about its orbit, Saturn's fine visibility on New Year's is not so odd. The Ringed Planet's 29.46-year period around the sun divides almost evenly into 1,000, so that Saturn has been witness to millennium celebrations since the last ice age. Its slow orbital motion ensures that it continues to grace New Years's skies for several additional years after each millennium begins.

So if 2002 opens with a night of good "seeing," then a New Year's resolution of the jovian belts and Cassini division might make a fine focus for any party gathering, a unique way for family and friends to start the year on an inspiring celestial note.

As the year rolls on, serious amateurs will find exciting things to see on any clear night. But observers who seek high voltage eye-openers won't get their kicks until spring. A true planetary spectacle illumines the sky during the last half of April: All five bright planets form a line in and around Taurus like a string of pearls.

Astrologers go into a feeding frenzy during such conjunctions, believing they affect everybody one way or another. But just as self-proclaimed psychics somehow never win the lottery, doomsday comes and goes every few years with each sensational planet bunching, and Earth pretty much continues unchanged, except that my socks keep vanishing.

In May the planet configuration mutates from a line into a tight ball, as if a shotgun blasted the evening heavens with brilliant sky-pellets. Venus and Mars in particular will sit extremely close together on the 10th. Like an unbalanced clothes dryer, the sun, moon, and every bright planet will hang out in one direction while we sit alone in the other.

August brings the great Perseid meteor shower, and for the first time in three years it unfolds under ideally dark, moonless skies. Where I live, everyone knows what such perfection means: It will be cloudy that night, continuing a 15-year-long supernatural August 11 overcast string that deserves to be investigated by science. But elsewhere, this is a good time to visit those friends out in the country.

Autumn offers a decent chance for what may be the year's greatest sky-spectacle, a dazzling Leonid meteor storm before dawn on November 18. The United States is presently favored for such one-a-second shooting stars. Then in December, Venus performs a gleaming three-way conjunction with the crescent moon and Mars on the 1st, just a few days before reaching its greatest brilliancy.

Later that month, Saturn attains a truly extraordinary opposition when it glows more brightly than anytime since 1973. Its ice-rings will be maximally facing us just as the planet soars to nearly straight overhead for the last time until the year 2032. Foreknowledge of this optimum photo-op of arguably the most beautiful celestial object might influence your decision whether to buy a new, more powerful telescope this year. (Do it!)

Those are the most dramatic predictable events for 2002, based on the solar system's tick-tock clockwork reliability. To dependably know when to look skyward this year, neat and orderly type-A people who meticulously plan things and dislike life's surprises could tape this page to their fridge (which has probably never held a week-old carton of leftover Chinese food). The rest of us (that is, everyone whose automobile trunk contains more than 41 items) can also pick these selections from column A, but *also* get a grab-bag choice from column B.

Column B stands for: Boo! Meaning, celestial events that jump out at you unexpectedly, that originate in the mysterious Realm of the Unplanned. The "A" list might bring you outdoors on a particular night, but it will be "B" that you're apt to remember forever.

For example, on April 6, 2000, a beautiful multi-planet conjunction attracted skygazers to the evening twilight. But suddenly, everyone in the northeastern United States saw brilliant rays at the zenith and bizarre blobs of red paint dripping like a hallucination down the western sky where it eerily enveloped the crescent moon. Bright enough to appear over light-polluted cities, it was one of the oddest, most brilliant and stunning aurorae in years. Because the northern lights peak not in the year that surrounds sunspot maximum but in the year following it, comparable fireworks could well be seen in 2002, especially around March. The POES satellite and the ACE spacecraft can supply Internet notice of possible activity, but there's still no substitute for checking out the heavens.

Similarly, the greatest exploding meteors (bolides) and fireballs typically burst across the heavens on non-meteor shower nights. The sky writhes with potential surprises but you don't see them if you're not already out there, looking up.

As for resolution's other meaning, resolve to visit a new (to you) astronomy club during a night when they're setting up at a rural site. You'll peer through instruments you normally never encounter and, better still, one of the members may well focus on a celestial object you have never thought of examining. We're all creatures of habit to a greater or lesser degree, and tend to look at the same things over and over again. Someone else may have different favorites, treasures you'll experience only if you place yourself in a new situation.

For something really new, and if time and budget permit, consider traveling. A celestial pilgrimage can be a wondrous experience. You may join me and other *Astronomy* staff members on a trip to central Alaska this March where dazzling aurorae are a near-nightly experience. Or come with us to Africa or Australia in December for the total solar eclipse. When else can you get the chance to be chased by the moon's shadow and a rhino at the same time?

This final palindromic year of our lives suggests symmetry and evenness. (A palindrome, you'll recall, is a word or number that's the same backward and forward, like 2002). Beginning and ending with unusual planetary brilliance in January and then December, 2002 indeed seems symbolized by balance. May such numerological poise spill over to bring us all a year of stability and joy. A

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*Bob Berman's "Strange Universe" column is a monthly feature in* Astronomy. *Berman also is the author of two wonderful guides for astronomers:* Secrets of the Night Sky *and* Cosmic Adventure.

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By Dale Lowdermilk
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*Stellarvue, P.O. Box 7515, Auburn, CA 95604–7515; (530) 878-4658; e-mail, vic@stellarvue.com; website, http://www.stellarvue.com.*

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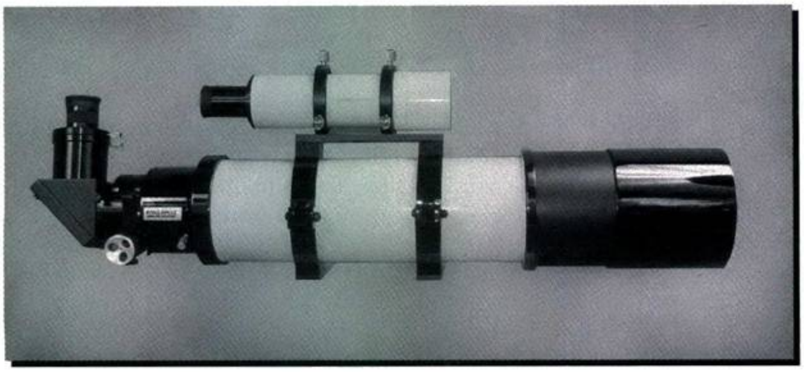

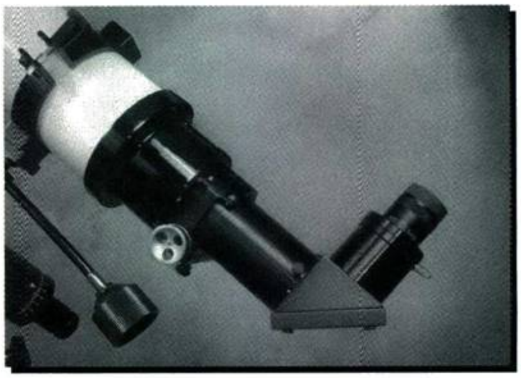

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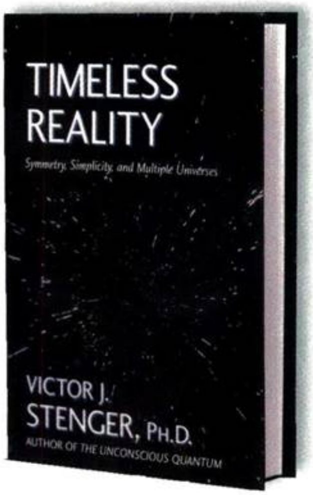

TIMELESS REALITY
Symmetry, Simplicity, and Multiple Universes
VICTOR J. STENGER, PH.D.
AUTHOR OF THE UNCONSCIOUS QUANTUM

### Timeless Reality: Symmetry, Simplicity, and Multiple Universes

Victor J. Stenger, 340 pages, Prometheus Books, Amherst, New York, 2000; ISBN 1-57392-859-3, hardcover, $33.

▶ Everyday experiences lead us to believe that time flows in one direction — always forward. And, the Second Law of Thermodynamics tells us that the tendency of the universe is toward greater entropy or disorder. This is why we never see a broken cup spontaneously reassemble into its original, unbroken form. Time reversal is the stuff of science fiction. But, as the saying goes, the truth may be stranger than fiction.

In *Timeless Reality*, Victor J. Stenger, retired professor of physics and astronomy at the University of Hawaii, argues that time is, in fact, reversible. The idea of absolute time and an absolute now is strictly a classical physics notion, courtesy of Sir Isaac Newton. At the turn of the 20th century, however, physicists like Einstein, Dirac, and Schrödinger showed us that the universe we live in is dramatically different from our everyday experiences. Stenger expertly leads us through the development of this brave new universe and the surprising implications.

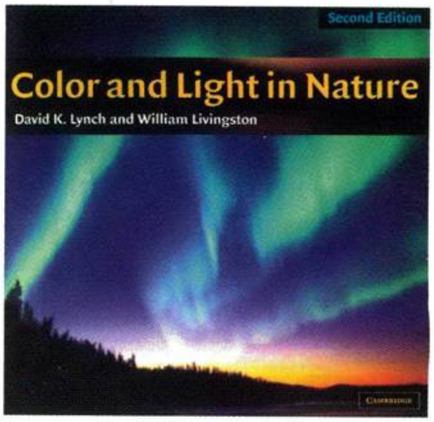
He begins with a historical overview of humanity's ideas and perceptions of reality, follows that with a discussion of paradigm shifts in scientific thought, and throws in an obligatory discussion of relativistic physics to emphasize the death of Newton's notions of absolute time and absolute simultaneity. Stenger identifies three arrows of time — the thermodynamic arrow, the cosmological arrow, and the radiation arrow — and argues that all three are indistinguishable. Ultimately, he concludes that these arrows of time do not reveal a deterministic law demanding that time immutably flows from past to present; rather, these so-called arrows of time are statistical statements of what is most likely to occur. Thus, it may be extremely improbable that our coffee cup magically reassembles into its former self after falling off a table, but is not impossible.

Having laid the foundation for his idea of time reversibility being possible — albeit highly improbable in our classical world — Stenger takes us into the quantum world. Here he breaks much new ground, explaining the evolution of quantum physics and various interpretations, including the Copenhagen interpretation and Schrödinger's cat. We also learn why Einstein had such a great distaste for quantum physics: Quantum physics as it is stated is either incomplete or it is superluminal, requiring signaling faster than the speed of light. In the chapters that follow, however, Stenger shows that this difficulty of faster-than-light signals is easily avoided if time is reversible. Within this timeless reality, it is possible that there exists a multitude of universes — each with their own unique structures and laws.

Overall, *Timeless Reality* is well written and quite fun. Stenger's tone is generally conversational, although a bit didactic at some points. If you've read other books on this subject lately, you could skip the first three chapters. A few of the discussions get heavy-handed and those who are faint of (physics) heart can skim the discussions of quantum mechanical state vectors, Hilbert spaces, and the like without too much loss. The book features some good illustrations and a handy glossary of physics, astronomy, and cosmology terms.

In *Timeless Reality* you'll also find some genuinely unique physics that you haven't read in any other popular astronomy book. This is a particularly nice feature, and — as Stenger mentions several times — I, too, found myself thinking, "Gee, they never talked about that when I was in grad school."

*Timeless Reality* is at heart a book about astrophysics. Stenger will open your eyes to some fascinating ideas about space, time, and reality. — *Jennifer Birriel, Morehead State University*


Second Edition
Color and Light in Nature
David K. Lynch and William Livingston
CAMBRIDGE

### Color and Light in Nature, Second Edition

David K. Lynch and William Livingston, 277 pages, Cambridge University Press, New York, 2001; ISBN 0-521-77284-2; hardcover, $85; ISBN 0-521-77504-3; softcover, $29.95.

▶ *Color and Light in Nature* serves double duty as both a coffee-table book and a textbook on the phenomenon of light. Profusely illustrated with color and black-and-white photos and line diagrams, the eight chapters tell the story of how light reacts to Earth. Here is stuff you've been seeing all your life. Now you can read about the science behind it.

Lynch and Livingston start readers off by discussing shadows and then moving through clear air, water, ice, and all the different distortions that result as light reacts with each. Blinks and glints and Bottlinger's rings are all explained in memorable terms, as are more common phenomena. A reference section rounds out each chapter.

Naked-eye astronomy and all facets of observing — from the eye's anatomy and the physiology of vision to the physics of polarization and observing tools — cap the science portion of the book. The final chapter

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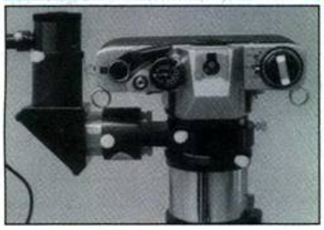

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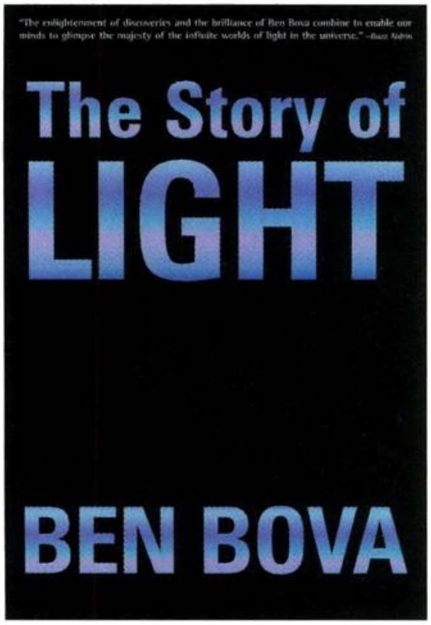
is a picture essay on various exotic cloud formations. A glossary and extensive index helps readers understand terms or seek related subjects. — *Carol Ryback, associate editor*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The Story of
LIGHT
BEN BOVA

### The Story of Light

Ben Bova, 356 pages, Sourcebooks, Naperville, Illinois, 2001; ISBN 1-57071-785-0; hardcover, $24.95.

▶ Ben Bova divides *The Story of Light* into four "books" that become increasingly more interesting. However, you can also let your curiosity guide you through it instead. Book I, "To See," consists of eight chapters that describe and explain light and how it governs the biology, evolution, and behavior of living creatures. This first section reads like a refresher junior-high science lesson, presented in an easy style that welcomes skimming.

Book II, "To Learn," discusses the history of the scientific endeavors that determined some of light's properties. All the famous names are here. From Archimedes's fabled light-beam weapon to Thomas Young's interference patterns to Heinrich Hertz and his experiments with electromagnetic energy and more, readers get an overview of what formed the basis of our current state of physical science knowledge.

Likewise, Book III, "To Use," explains just how integrated "light" (the electromagnetic spectrum) is in our daily lives. More than that, however, Bova shows readers how we've been able to manipulate light to our advantage. It not only helps define our world, but also serves as a tool unto itself.

All of this leads to Book IV, "To Seek," and the ultimate power of light: The more we learn about it, the more we can research our own beginnings.

*The Story of Light* provides a fascinating look at a life phenonemon that we take for granted, even though it influences everyone every day. While topics may prove too elementary for academics, Bova teaches a painless science lesson without becoming overwhelmed with technical jargon. A glossary and bibliography are included for further reading. — *C. R.*

### Extreme Stars: At the Edge of Creation

James Kaler, 236 pages, Cambridge University Press, New York, 2001: ISBN 0521-40262-X; hardcover, $34.95.

▶ We are intrigued by superlatives: Longest, shortest, largest, smallest, brightest, dimmest — extremes that simultaneously defy and define the average. James Kaler's *Extreme Stars: At the Edge of Creation* is an entrancing tour of the weirdest stellar bodies that both breaks and builds intuition about what it means to be a star.

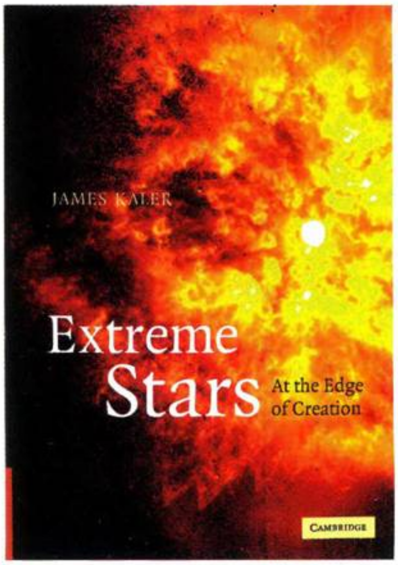
*Extreme Stars* is rigorous enough to be used as an introductory textbook, but light enough for an amateur or scientist to read for pleasure, a rare and delicate balance for a trade book. For example, Kaler takes readers on a series of intellectual day jaunts as he explores the interesting fringes of the Hertzsprung-Russell diagram, then finishes the ten-chapter tour by providing a good working knowledge of basic stellar astronomy.

Kaler starts with the closest and most-studied star, the sun, and vaults into a "Cliff Notes" survey of the physics background to stellar astronomy: atomic physics, spectral measurements, the H-R diagram, stellar classifications, etc. Each subsequent chapter explores a different extreme — faintest, coolest, hottest, brightest, largest, smallest, youngest, oldest, and strangest. (Avid *Astronomy* readers will recognize some of the chapters from a series of articles published earlier; but these have been reworked to form a complete, smoothly flowing tour.)

The tour includes even the faintest stars — red and brown dwarfs — which are surprisingly active and interesting. At a temperature cooler than the filament of a halogen light bulb, tiny young red dwarfs can still spew coronal flares literally thousands of times larger than those on the sun. At the smallest end of the scale are gas giant planets, and in a minor digression Kaler discusses the exciting, newly discovered zoo of extrasolar planets.

The coolest true stars are giants that distribute their moderate luminosity over surfaces larger than Mars's orbit. Carbon giants, the very coolest stars at about 2000 K, are puzzles in their own right, with nucleosynthesis happening throughout the star and convection actively dredging carbon from the deep nuclear burning zone to the surface.

The central irony of stellar physics is that stellar cores get hotter as they cool off, contracting to ever-higher densities and temperatures that sustain nuclear fusion as lighter elements are used up. Hence, the hottest stars, at about 100,000 K, are the stellar remnants at the centers of planetary nebulae, naked stellar cores surrounded by the scattered remains of their former cool-giant envelopes.



White dwarfs, neutron stars, pulsars, and stellar black holes form the smallest and densest family of stars. Readers

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Understanding of the youngest, still-forming stars and planets has developed greatly in the last several years. Kaler starts with carbonaceous chondrites on Earth and takes us through clouds of interstellar hydrocarbons to view young T-Tauri stars, Herbig-Haro objects, and the famous Eagle Nebula star-formation region. The oldest stars nucleate a discussion of galaxies, redshift, and cosmology.

Kaler's selection of "strangest" stars comprises a fascinating sideshow of supernova remnants, Wolf-Rayet stars, weird dynamic objects, puzzling planetary nebulae, triple stars, and a bizarre double star with an orbital speed more than 15 percent of the speed of light.

*Extreme Stars* is an interesting, engaging, and thorough presentation of stellar astronomy from a new perspective. Whether you enjoy casual stargazing or teach astronomy, this book's careful treatment and fresh outlook make it an excellent resource and a delightful read. — *Craig DeForest, Southwest Research Institute, Boulder, Colorado*

## The Webweaver Picks; Take a Virtual Tour

by Richard J. Bartlett

Galileo Galilei lived in an age when contemporary wisdom claimed everything revolved around Earth. On January 7, 1610, he saw something no human had ever seen before. Through the nights that followed, he watched as four tiny stars danced around the giant world of Jupiter. His discovery forever changed our view of the universe. The Institute and Museum of the History of Science in Florence dedicated a room to Galileo, Italy's greatest astronomer. You can visit the room and take a virtual tour at http://www.imss.fi.it/museo/4/index.html. Artifacts on display include two of Galileo's telescopes, the objective lens from the telescope he used to discover the moons, and his index finger. Each artifact has its own page with accompanying images and text.

For a more detailed insight into his life and work, visit Rice University's Galileo Project at http://es.rice.edu/ES/humsoc/Galileo/. Although some of the pages are rather text-heavy, there are some fascinating articles describing his home, family and work. His contemporaries, the world around him and the historical events occurring at that time are also detailed. Perhaps most significantly, letters from Galileo's daughter are also reproduced here.

Both websites serve as excellent resources for those wishing to learn more about this great man, but what of the moons themselves? To Galileo, each tiny star appeared randomly dispersed upon either side of the planet. He had no idea where each moon would appear from night to night. Today, we can predict their positions. This would be nothing short of magic for Galileo.

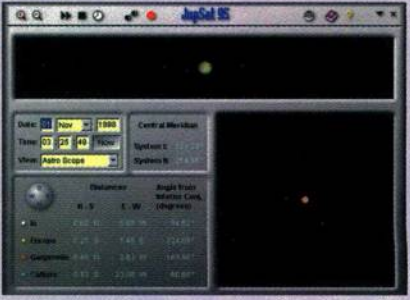
Dan Bruton of the Stephen F. Austin State University has written four DOS freeware programs to help amateurs track not only the Galilean satellites, but also Jupiter's cloud features and the moons of Saturn. Each of these is available from http://www.physics.sfasu.edu/astro/dansoftware.html and run on any Windows operating system from 3.x onward.

The first, Galilean Satellites, downloads as a 52K zipped file. The program displays a view of the moons as seen from Earth, a view of the jovian system from above Jupiter's south pole, and a graph depicting the movements of the moons over a seven-day period. Users can set a new date and time and animate the display to show the movements of the moons. Additionally, it depicts the positions of the moons during the impacts of the Shoemaker-Levy 9 remnants. There's also a "night-time" option that turns the display red to avoid ruining your eyes' sensitivity to the darkness. Although there is no print option, the program is free and downloads in seconds.

The second of Bruton's programs, Jovian Moon Events, is a little more technical in that it calculates the transit, eclipse, occultation and shadow times of the moons for any given month. Found at the same location as Galilean Satellites, it downloads as a larger 127K zipped file.

This program's biggest problem lies in the time it takes to calculate the Galilean events. On slower machines it takes two to three minutes for a single day's events. Users can only calculate events for one month at a time, so the entire process could take up to 90 minutes to complete. It outputs results to a file with a ".jme" extension. The program fails to mention that the file can be opened and printed using either Notepad or Word.

Bruton's third program is called Tracker and depicts the cloud features of Jupiter for any given time and date. Both north and south hemispheres are represented and the program shows not only the Great Red Spot, but also its smaller white cousins. Visitors can animate the display and go back in time to recreate the impacts of the Shoemaker-Levy 9 fragments. Available from the same URL as the others, the program downloads as a 59K zipped file.



Finally, check out JupSat95 by Gary Nugent. The program downloads from http://indigo.ie/~gnugent/JupSat95/ as a 754K self-extracting file for Windows 95/98/2000 and NT. Although the program is shareware, all its functions are enabled and there is no time limit set before you have to register. Instead, it is up to the generosity of each user to donate $5 to the author.

By far the most graphically appealing of the satellite predictors, JupSat95 allows you to plot the positions of the Galilean moons for any given date. The views presented are the same as Galilean Satellites, but the program comes with a few extra options. The view from Earth zooms in and out and changes for Northern or Southern Hemisphere observers. There are three settings to display the view: through a telescope, star diagonal or binoculars. Additionally, the transit times for the Great Red Spot can also be calculated. One crucial difference between JupSat95 and Galilean Satellites is the option to print the results

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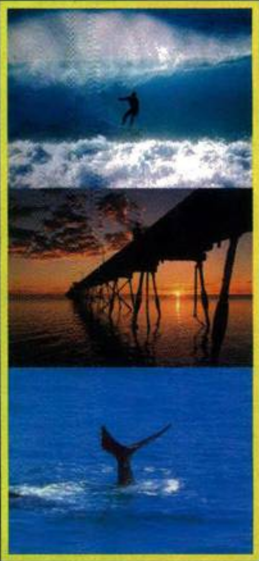

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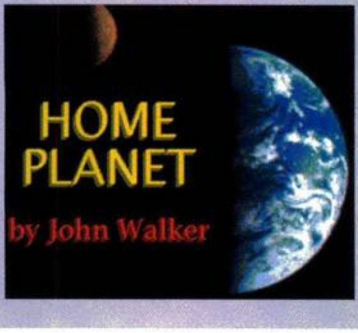
## Webweaver Picks (continued)

directly from the program. The quality of the printout is also good.

And while Galileo was a visionary, he could scarcely have imagined the fascination those moons still hold some 400 years later. For those who wish to show a real-time representation of the moons on their website, Nugent has also created a free Java applet, available from http://indigo.ie/~gnugent/dnso/software.htm. Just scroll down to the "Java Applets" section and download the 13K zipped file. Nugent includes text files and a sample webpage to show you how to incorporate the program into your site.



Finally there's Satellites Of Saturn, the last of Bruton's software. This freeware DOS program calculates and displays the positions of Saturn's largest moons. There are two main views — one from Earth-based telescopes and one looking down on Saturn from above a pole. As with the other programs, users can change the date and time and animate the display.

Features unique to this program include zooming in and out, identifying each moon with a key press, and generating a table that shows the relevant planetary data for the selected time and date. Unfortunately, as with Galilean Satellites, there is no way to print the results directly from the program. Download Satellites Of Saturn as a 76K zipped file from the URL listed above.

Another satellite plotter easily available online is Sat from Marzio Rivera. This abruptly named freeware program for Windows 95/98/2000 downloads as a 248K zipped file from http://www.astrosoftware.net/. The program calculates the positions of the Galilean satellites and the major moons of Saturn. It's quick and easy to use and allows users to either print the results or generate a bitmap graphic. Unfortunately, the printout isn't very clear, and although a bitmap graphic comes in handy for those with a website, when creating a graphic depicting the satellites of Saturn, it isn't obvious which moon is which.

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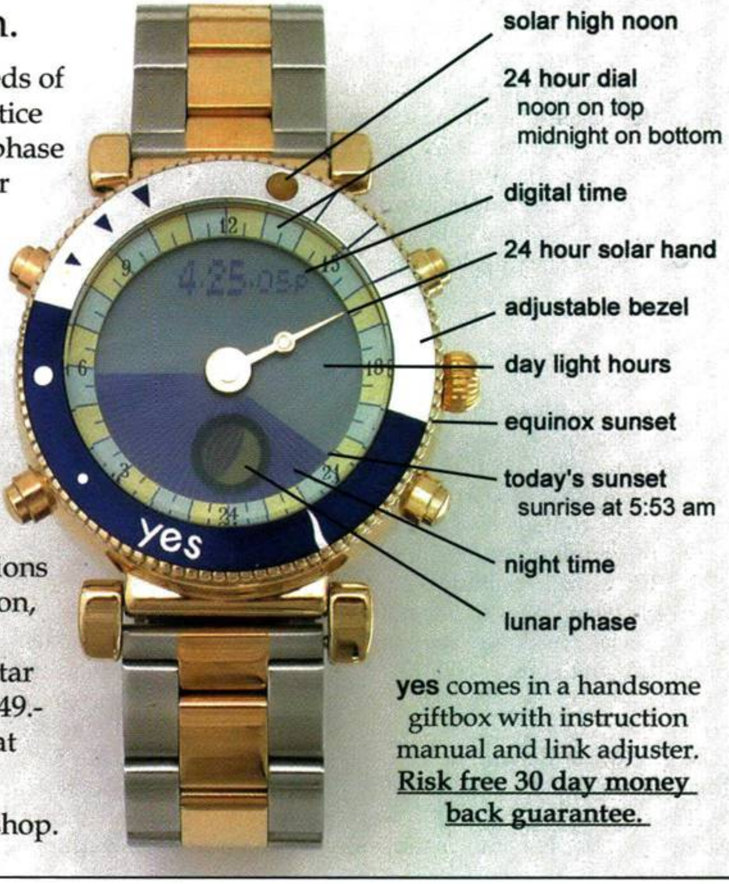

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The Hilton Washington and Towers, Washington, D.C. For information on scientific programming or exhibit information, contact Diana Alexander, (202) 328–2010; e-mail, diana@aas.org; for registration information, contact Zuzana Hanova, (202) 328–2010; e-mail, reg-help@aas.org; AAS website, http://www.aas.org.

**JANUARY 7**

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New York, New York. **Amir Aczel, The Riddle of the Compass**. Part of the Distinguished Authors in Astronomy lecture series. 7:30 P.M. For further information, contact the Hayden Planetarium at (212) 769–5900; website, http://www.amnh.org/education/hayden.html.

**JANUARY 19–20**

### All-India Amateur Astronomers' Meet

PRL Auditorium, Gujarat University, Ahmedabad, India. 10 A.M.–5 P.M. Hosted by the Astronomy Club Ahmedabad. For more information, view the club website, www.astronomy-club.freeservers.com.

**JANUARY 29**

### Alexander Vilenkin — The Cosmological Constant

Morrison Planetarium at the California Academy of Sciences, located in Golden Gate Park, San Francisco, California. 7:30 P.M. Tickets are $3; advance purchase recommended. Contact (415) 750–7127; website, http://www.calacademy.org/planetarium.

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| 10" SCT | 57 |

### Dew Shields!

| | |
|---|---|
| ETX90mm | 27 |
| ETX125/Nexstar5 | 34 |
| 7"/8" | 54 |
| 10" | 64 |
| 12" | 85 |

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### Zero-Image Shift Focusers!

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|---|---|
| **NGF-SE** | $169 |
| **NGF-S** w/motor | 269 |

**Newtonian:**

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| **RCF1** Mini 1.25" | 79 |
| **NGF3** Mini 1.25" | 99 |
| **NGF DX3** 2-inch | 159 |

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| 10x50 Ultima | 229 |
| 20x80 Deluxe | 449 |

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| Redshift-4 PC | 49 |
| StarryNight Pro | 129 |
| Starry Backyard | 49 |
| SkyMap Pro 7 | 95 |

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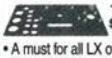

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| 20 or 25mm | 97 |
| 32 or 40mm | 112 |
| 55mm | 228 |

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| 19mm | 240 |
| 22mm | 280 |
| 27mm | 330 |
| 35mm | 365 |

**Radian-60°** (each)

| | |
|---|---|
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| 8, 10, 12mm | 240 |
| 14, 18mm | 240 |

**Nagler-82°**

| | |
|---|---|
| 4.8mm | 155 |
| 5mm Type6 | 280 |
| 7mm | 190 |
| 7mm Type6 | 280 |
| 9mm Type6 | 280 |
| 12mm Type4 | 355 |
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| 17mm Type4 | 385 |
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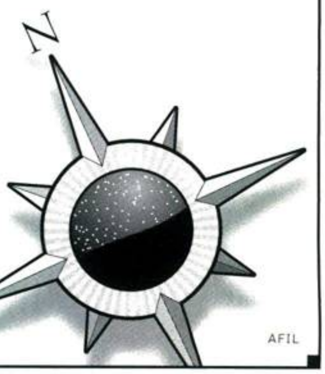

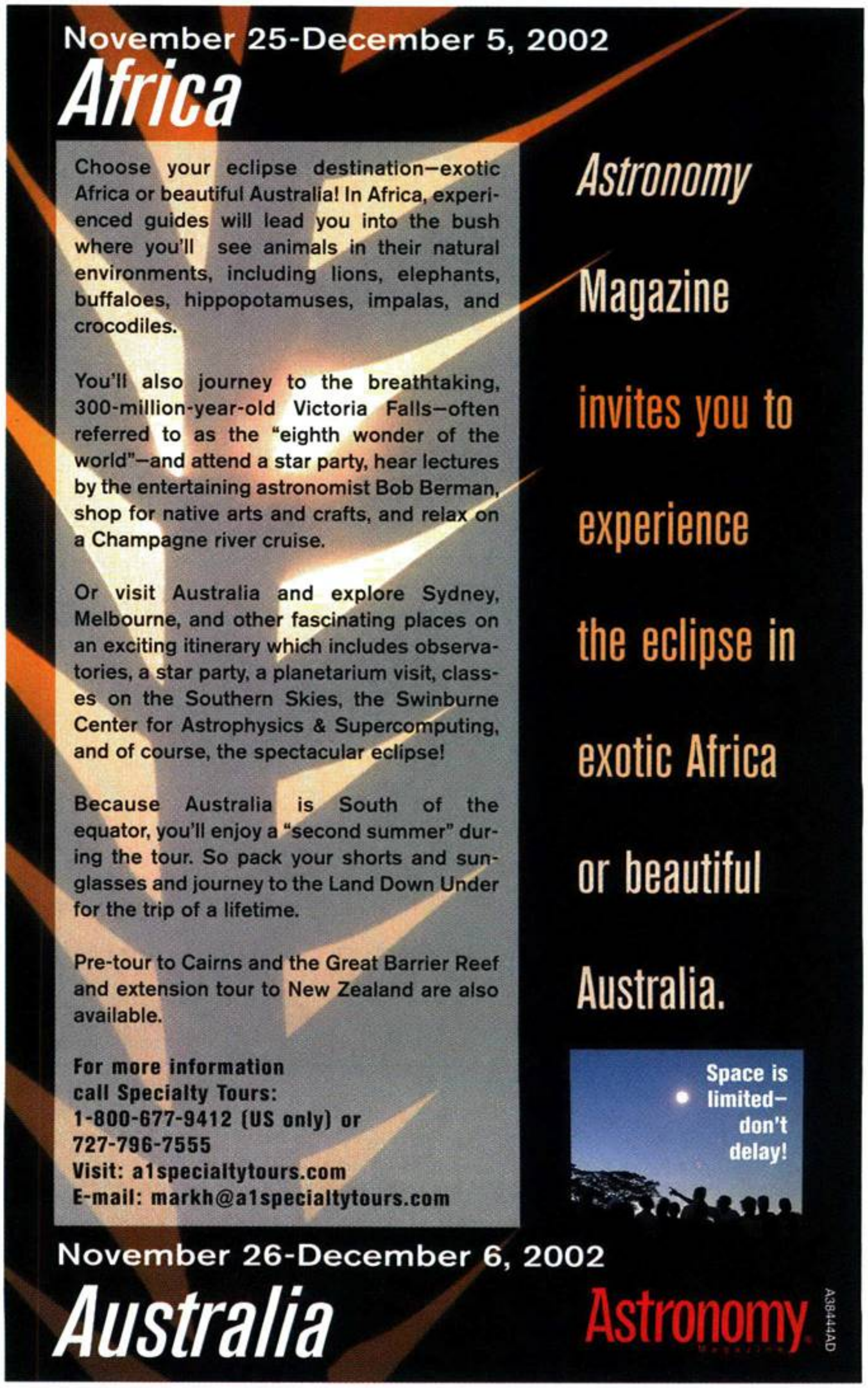

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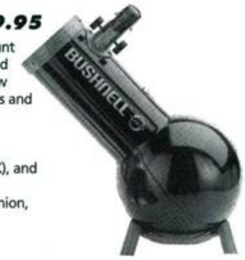

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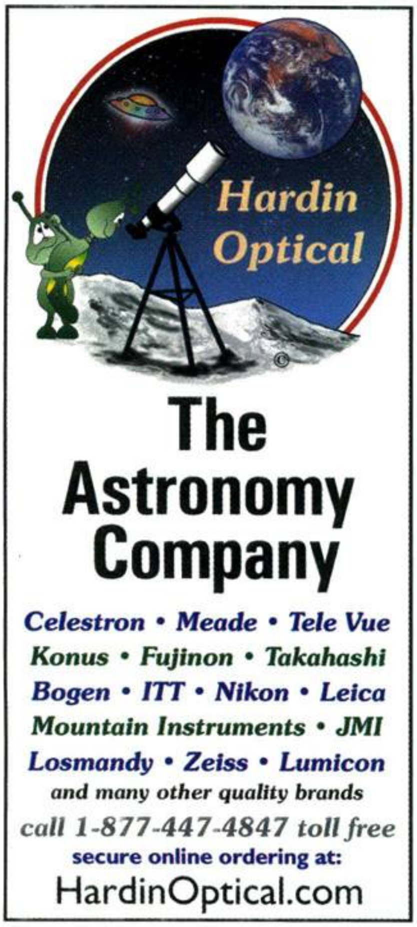
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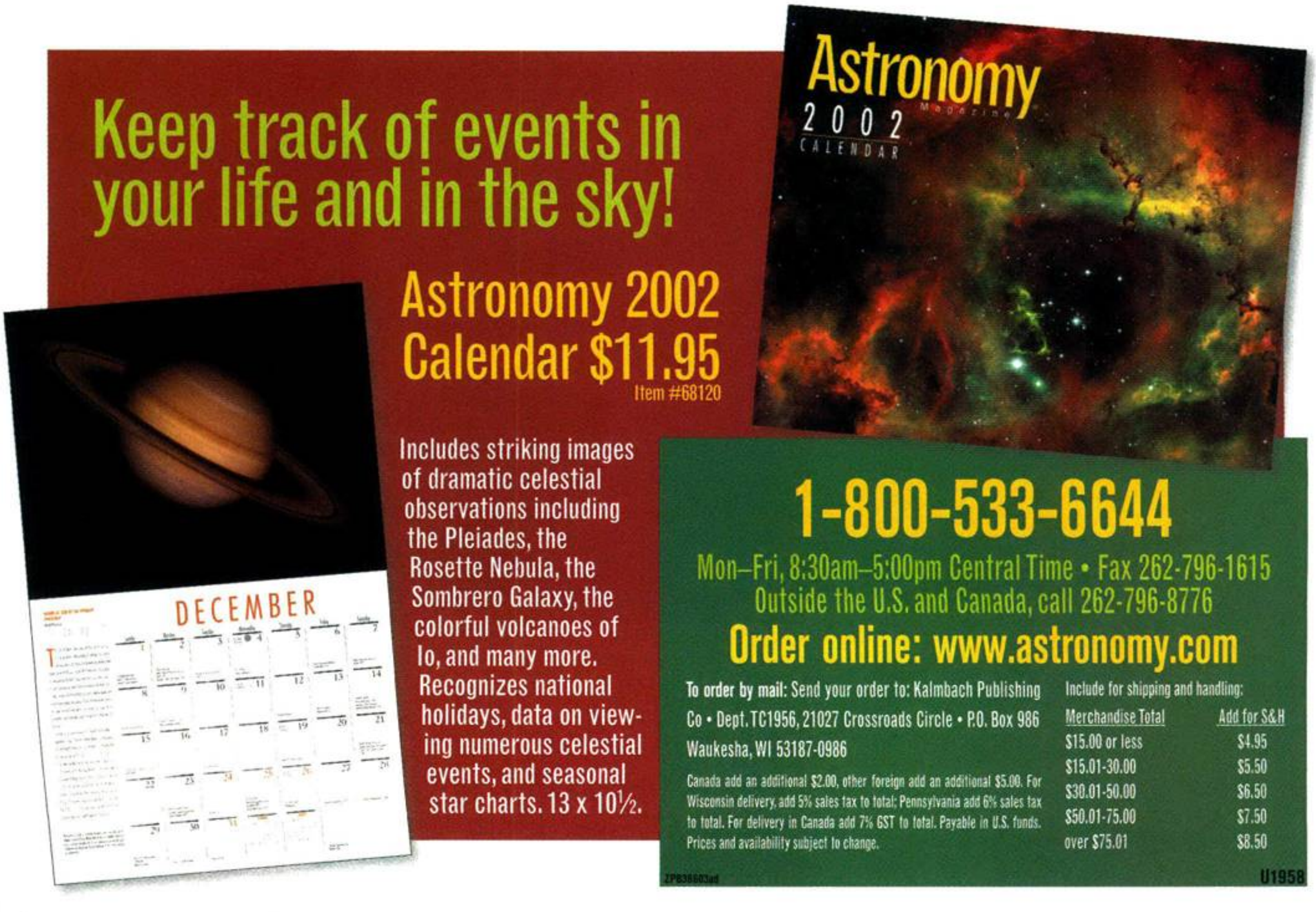
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(Required by 39 USC 3685)

1. Publication title: ASTRONOMY

2. Publication No.: 531-350

3. Filing date: October 01, 2001

4. Issue frequency: monthly

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14. Issue date for circulation data below: September 2001

15. Extent and nature of circulation:

| | Average no. copies each issue during preceding 12 months | Actual no. copies of single issue published nearest to filing date |
|---|---|---|
| A. Total number of copies (net press run) | 249,436 | 241,009 |
| B. Paid and/or requested circulation | | |
| 1. Paid/requested outside-county mail subscriptions | 114,018 | 114,369 |
| 2. Paid in-county subscriptions | N/A | N/A |
| 3. Sales through dealers and carriers, street vendors, counter sales, and other non-USPS paid distribution | 48,486 | 44,461 |
| 4. Other classes mailed through the USPS | N/A | N/A |
| C. Total paid and/or requested circulation (sum of 15B1 and 15B2) | 162,504 | 158,830 |
| D. Free distribution by mail (samples, complimentary, and other free) | 218 | 178 |
| E. Free distribution outside the mail (carriers or other means) | -0- | -0- |
| F. Total free distribution (sum of 15D and 15E) | 218 | 178 |
| G. Total distribution (sum of 15C and 15F) | 162,722 | 159,008 |
| H. Copies not distributed | 86,714 | 82,001 |
| I. Total (sum of 15G and 15H) | 249,436 | 241,009 |
| Percent paid and/or requested circulation: | 99.87% | 99.89% |

16. Publication of statement of ownership: Publication required. Printed in the January 2002 issue of this publication.

17. I certify that the statements made by me above are correct and complete. Michelle Spehr, Circulation Manager. Date: September 27, 2001

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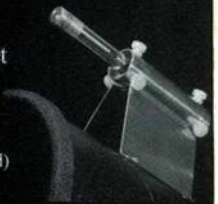

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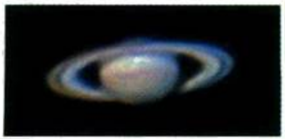

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# HOT SHOTS

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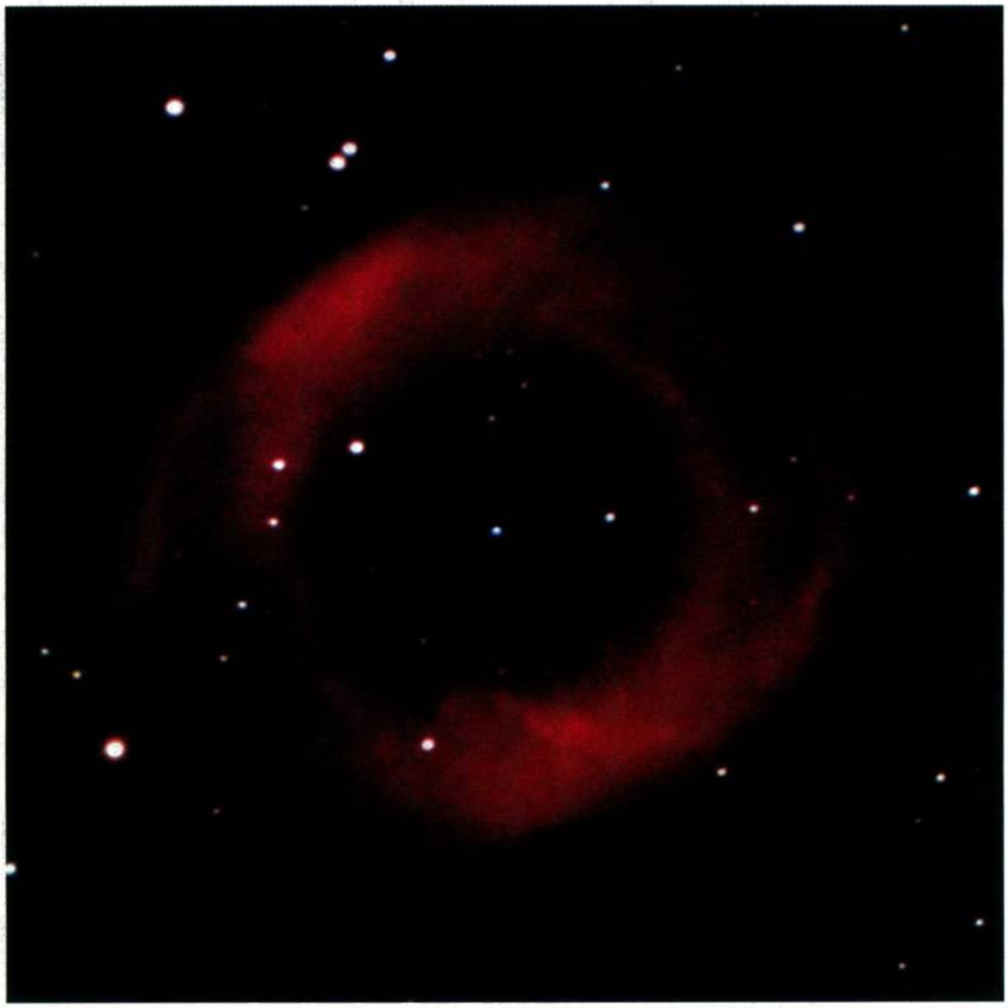
## Seeing More than Meets the Eye

▶ My first look at a deep-space object came in 1970, when I was 19 years old. It was M57, the Ring Nebula. I wasn't accustomed to looking at dim, deep-space objects and I kept trying to get a sharp focus on the ring. It appeared to move in and out of view, alternating with a gray disk. As I tried to see the ring more clearly, I realized that I saw it best when I didn't look directly at it — I had stumbled onto averted vision.

Later, in medical school, I learned that the rods in the eye's retina are more sensitive to dim light than are the cones. Rods are also located off-center from the visual axis of the eye.

Unfortunately, the rods don't detect color, like the cones, so we cannot discern colors of dimmer deep-space objects. Averted vision, therefore, engages only the light-sensitive rods — in contrast to a direct vision image that we normally see, which employs both types of receptors.

I began observing from a suburb of St. Louis, Missouri. Sue, my girlfriend (now my wife) showed me the constellations, which she learned from her uncle. We began with naked-eye observations and used her dad's binoculars for a couple of weeks. Then I bought a 60mm refractor on an alt-azimuth mount. It took us a while to figure out how to align the finderscope



**Helix Nebula (NGC 7293)**

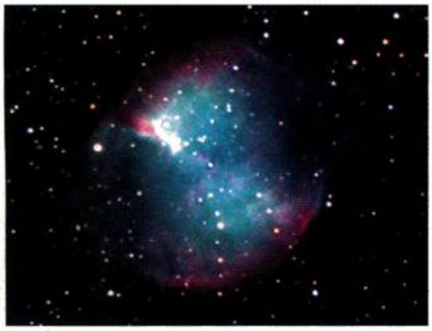
**GIANNI TUMINO AND MELANIA PLUCHINOTTA**

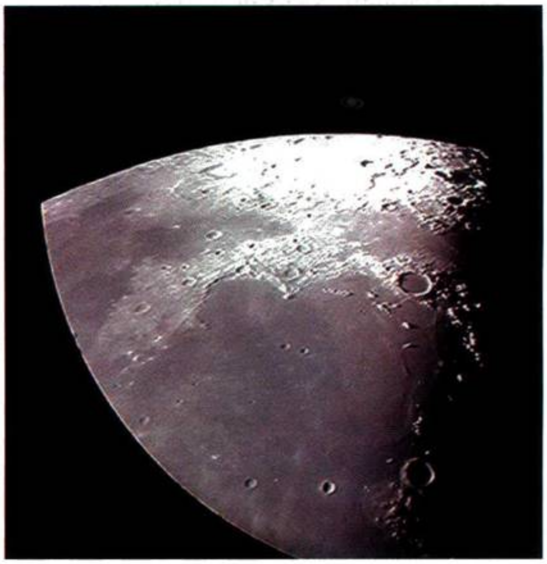
(12-inch SCT at f/6.5, Kodak E-200 film pushed two stops, two 30-minute exposures)

**M27**

**AL KELLY**

(8-inch SCT at f/10, Starlight Express MX916 CCD camera, 52-minute composite exposure taken October 7, 2001)





**Moon occults Saturn**

**PATRICK FORSTER**

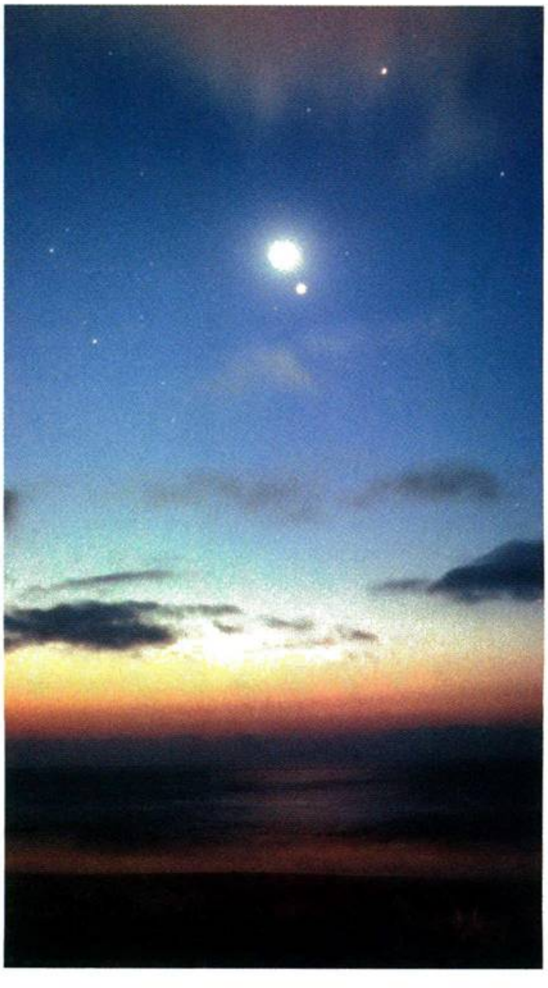
(6-inch reflector at f/68, taken September 10, 2001) with the main optical tube assembly and how to actually locate objects.

Sue and I put the scope on the brightest "star" in the sky that night and soon realized that we had discovered Jupiter. Our excitement was almost uncontainable. We had read about the Galilean moons, Jupiter's bands, and the Great Red Spot, so we spent about an hour observing them. Then we put the scope on the second brightest "star" in the sky and found Saturn — rings and all. That did it.

Within a month, I bought a 6-inch f/8 Newtonian reflector with quality optics, pier mount, analog setting circles, and a right ascension drive.

We set up that scope in my dad's driveway, and aimed it at M57. When we called my dad out to look, his first response was, "What, that little fuzzy thing?" I shared my averted vision experience with him and he agreed that M57 was easier to see that way, but still wasn't overly impressed — but he loved those views of Jupiter and Saturn. My mom politely looked at each object that night but said nothing more profound than, "Oh, yeah." For some reason, she had problems focusing, and even had difficulty adapting to the eye relief of my 40mm Kellner eyepiece.

The next night, we took the scope over to Sue's backyard and found M57 again. We showed her parents, but their responses were similar to my dad's reaction. Then we found our second deep-space object — M13 — that very night, which seemed to make more of an impact on everyone. About half the neighborhood kids showed up to see M13, M57, Jupiter,



**Sagittarius and Mars**

ERNIE MASTROIANNI

(58mm lens at f/1.2, Fujicolor Press 800 film, 30-second exposure taken August 17, 2001)

**Solar Flare**

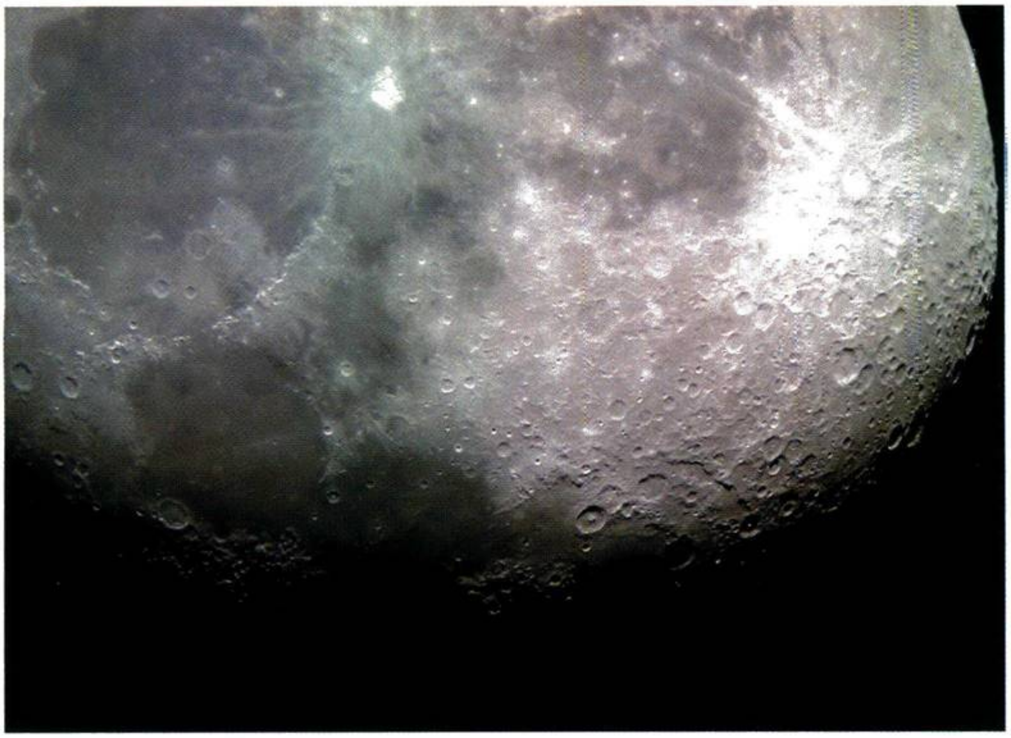
JACK NEWTON

(7-inch apochromatic refractor at f/32, 1/25-second exposure, H-α filter, Pictor 1616XTE CCD camera, taken September 27, 2001)

**Moon, Venus, and Jupiter in Gemini over the Atlantic Ocean**

GAVIN DONARUM

(35mm lens, Fuji Superia 800 X-tra film, 20-second exposure taken August 16, 2001)



**Moonscape**

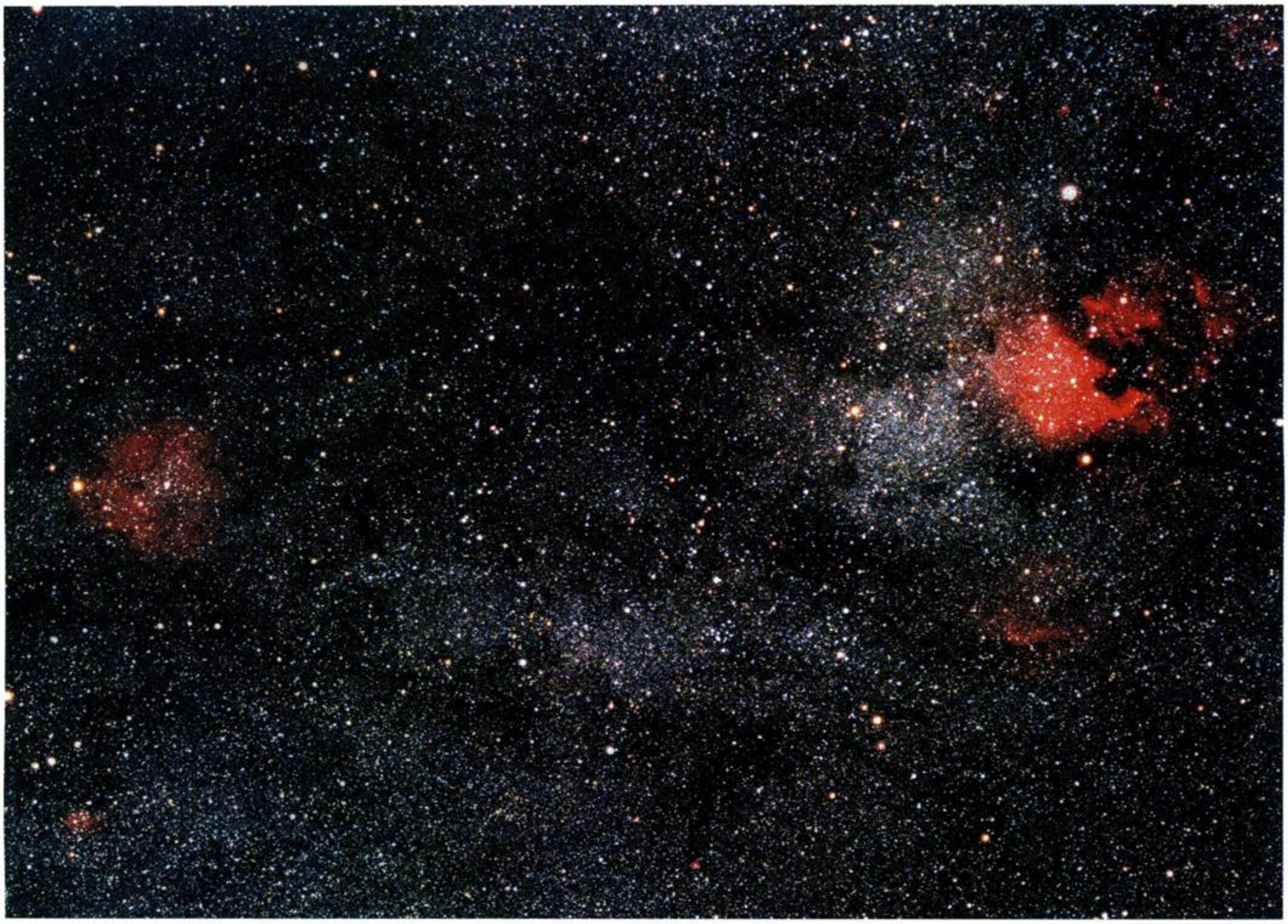
**RENÉ LALONDE**

(102mm ED refractor at f/44,
Nikon CoolPix 950
digital camera,
taken September 6, 2001)

**Cygnus-Cepheus Region**

**GIANNI TUMINO AND MELANIA PLUCHINOTTA**

(85mm lens at f/4, Kodak E-200
film push-processed two stops,
two 15-minute exposures)



and Saturn. Because a 6-inch Newtonian was regarded as a big telescope in those days, my scope was a hit wherever I took it. I've been hooked on astronomy ever since.

---

*Rich Jacobs specializes in internal medicine. He began taking CCD images in 1997. Visit his website at http://www.azastronomy.com.*

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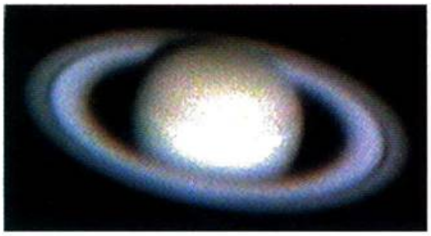
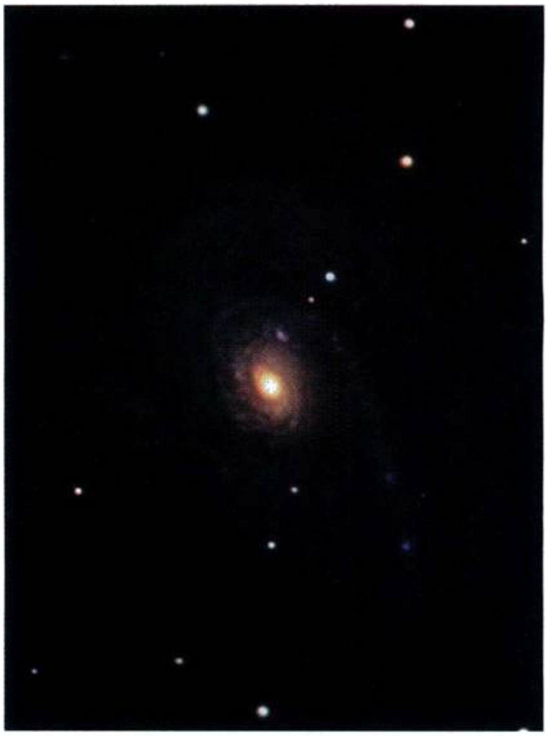




**Saturn**

ERNIE MASTROIANNI

(10-inch reflector at f/6.8, Nikon Coolpix 990 digital camera, ISO 100 film, ¼-second exposure taken August 29, 2001)

**NGC 772**

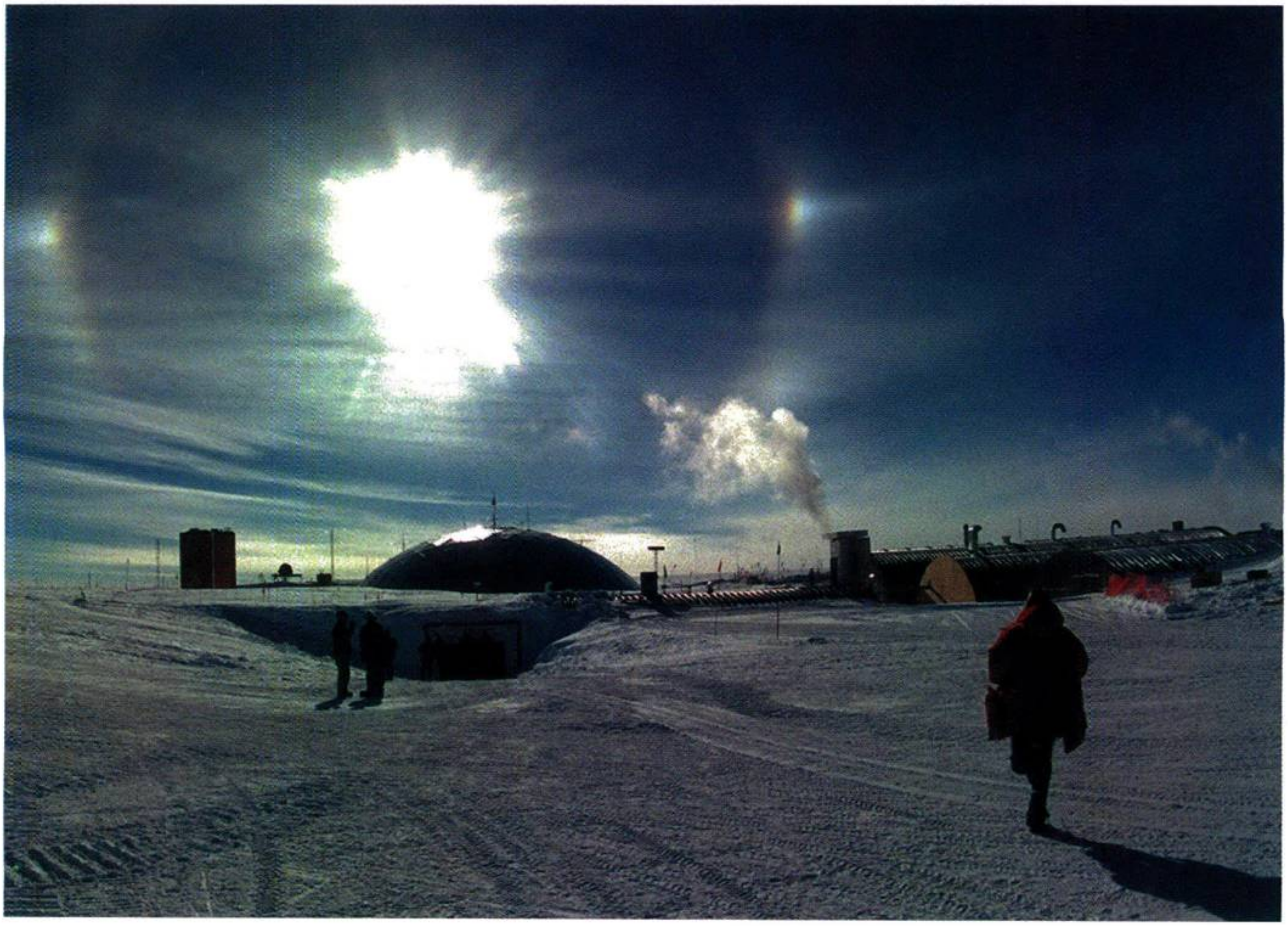
ROBERT GENDLER

(12.5-inch Ritchey-Chrétien scope at f/9, ST10 CCD camera, three-hour composite exposure)

**Sundogs in Antarctica**

ERNIE MASTROIANNI

(16mm fisheye lens at f/11, Fujicolor Superia 100 ISO film, taken January 5, 2001)



**Iridium flare bounded by Cygnus, Lyra, and Aquila**

JOE ORMAN

(50mm lens at f/2.8, Kodak Ektachrome P1600 film, 5-minute exposure taken June 24, 2001)

**Jupiter and the moon**

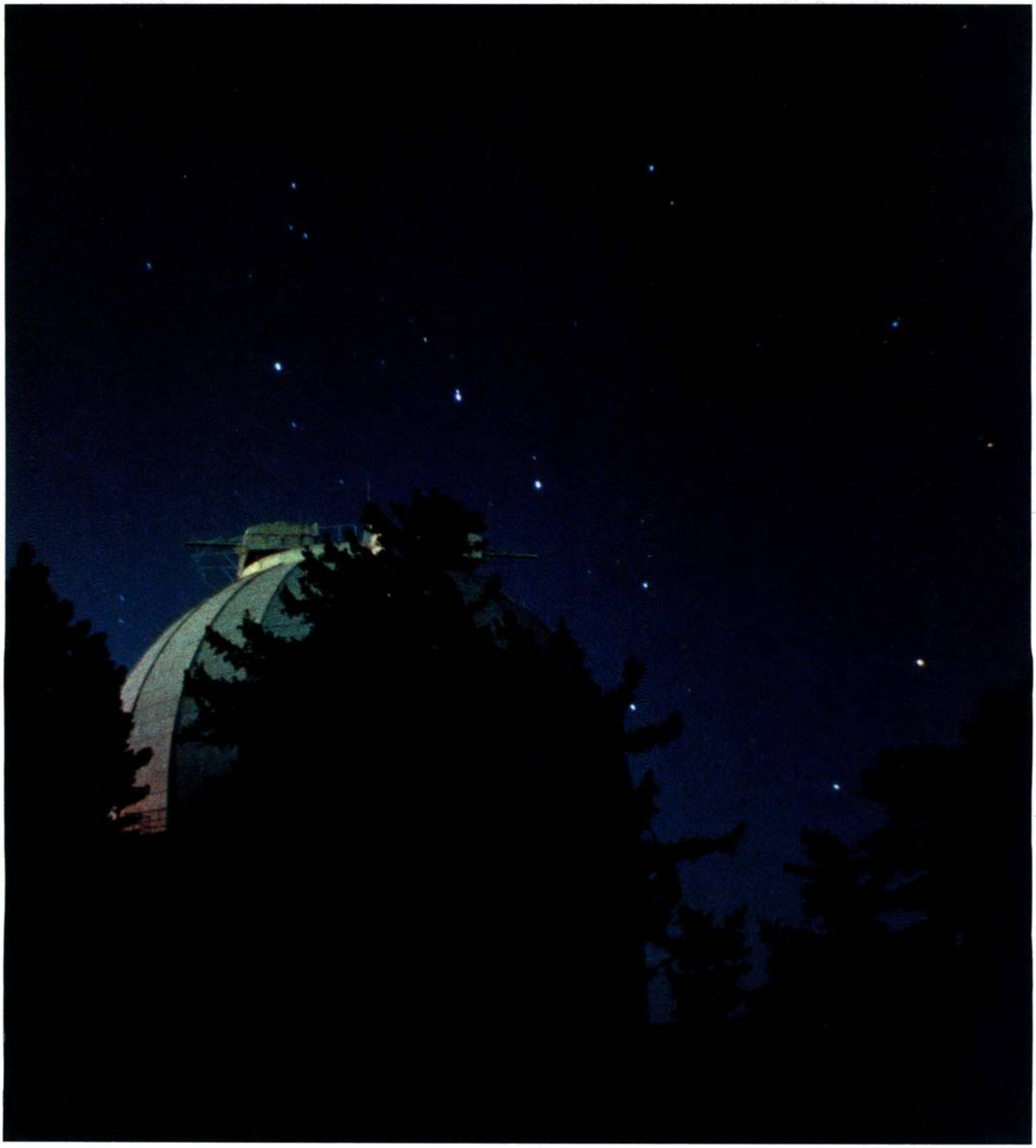
IVAN DRYER

(180mm lens at f/2.8, Kodak VS 100 film, taken September 12, 2001)

**IC 410 surrounding NGC 1893 in Auriga**

TOM DIANA

(4-inch refractor at f/8, Hypered Kodak PPF film, 50-minute exposure)



**Bear Watch: The Big Dipper**

DAN SCHECHTER

(50mm lens at f/1.4, Kodak E-200 film, 30-second exposure taken June 30, 2001)

Ursa Major nestles between the treetops and Mount Wilson Observatory's 100-inch Hooker telescope dome on a clear California night.

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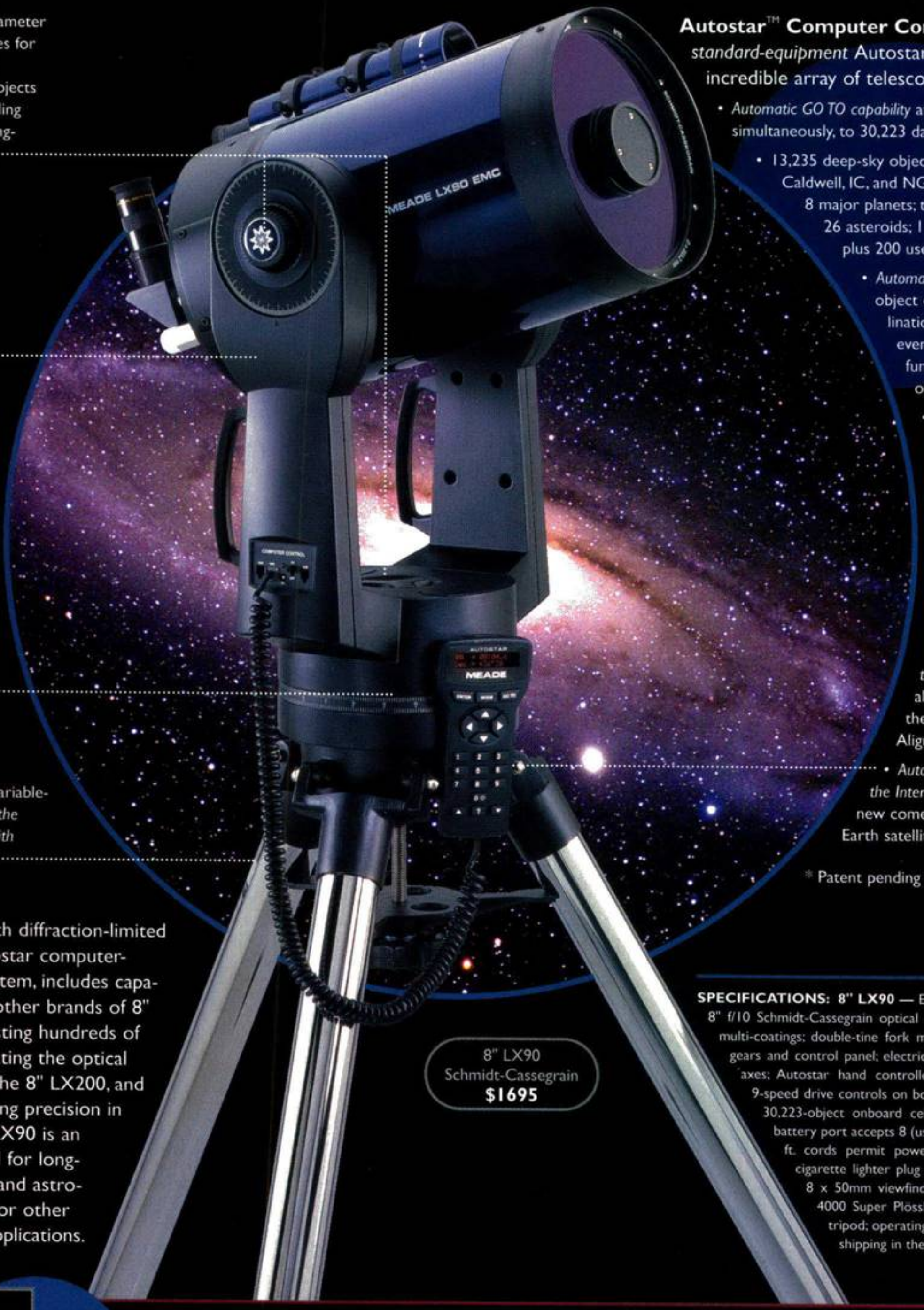

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